INSTRUCTION MANUAL

MODEL 160B

DIGITAL MULTIMETER

(AND MODEL 1602B DIGITAL OUTPUT)

KEITHLEY INSTRUMENTS

warranty

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof which, within a year after shipment, proves defective upon examination. We will pay local domestic surface freight costs.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and shipping instructions.

repairs and calibration

Keithley Instruments maintains a complete repair and calibration service as well as a standards laboratory in Cleveland, Ohio. A service facility is also located in Los Angeles for our west coast customers.

A Keithley service facility at our Munich, Germany office is available for our customers throughout Europe. Service in the United Kingdom can be handled at our office in Reading. Additionally, Keithley representatives in most countries maintain service and calibration facilities.

To insure prompt repair or recalibration service, please contact your local field representative or Keithley headquarters directly before returning the instrument. Estimates for repairs, normal recalibrations and calibrations traceable to the National Bureau of Standards are available upon request.

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THIRD PRINTING, SEPTEMBER 1976, CLEVELAND, OHIO, U.S.A.

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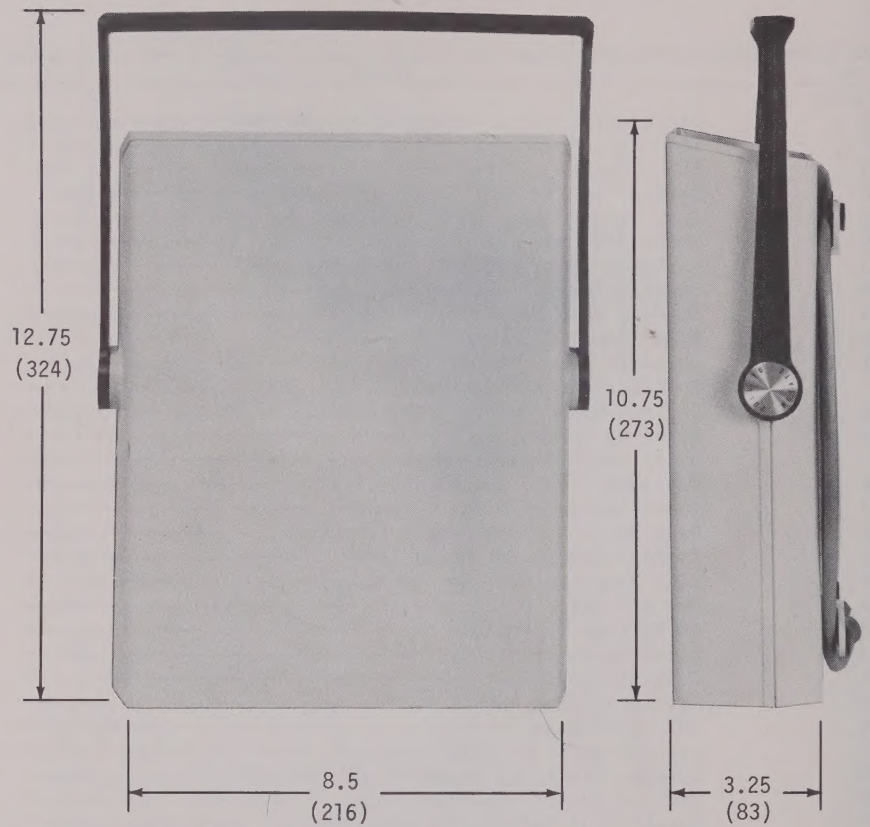


DIMENSIONS IN INCHES (MM)

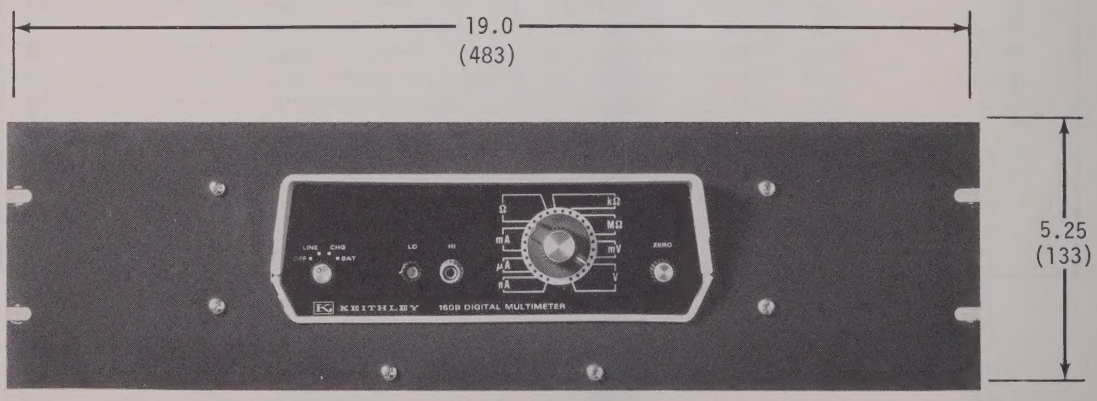


FIGURE 1. Dimensional Data.

SPECIFICATIONS

Calibrated at 25° ±3°C
Warranted for 1 year

AS A DC VOLTMETER

RANGE	MAXIMUM READING	ACCURACY ±(% of rdg + % of rng)		INPUT RESISTANCE	TEMPERATURE COEFFICIENT ±(% of rdg + % of rng)/°C		MAX. ALLOWABLE INPUT dc + peak ac
1 mV	1.999 mV	0.1%	0.1%	10 MΩ	0.01%	0.01%	600 V*
10 mV	19.99 mV	0.1%	0.1%	10 MΩ	0.01%	0.01%	600 V*
100 mV	199.9 mV	0.1%	0.1%	10 MΩ	0.01%	0.01%	600 V*
1 V	1.999 V	0.1%	0.1%	10 MΩ	0.01%	0.01%	1200 V
10 V	19.99 V	0.1%	0.1%	10 MΩ	0.01%	0.01%	1200 V
100 V	199.9 V	0.1%	0.1%	10 MΩ	0.01%	0.01%	1200 V
1000 V	1200 V	0.1%	0.1%	10 MΩ	0.01%	0.01%	1200 V

*1200 V momentary.

NORMAL MODE REJECTION RATIO: Greater than 80 dB above one digit on the 1-millivolt and 10-millivolt ranges, and greater than 60 dB above one digit on higher ranges, for voltages of line frequency or twice line frequency, with at least 1% of full range dc applied.

ZERO STABILITY: ±0.1 microvolts per °C.

COMMON MODE REJECTION RATIO (1 kΩ unbalance): Greater than 140 dB at dc and 40 to 200 Hz ac with at least 1% of full range dc applied. 1000 volts dc + peak-to-peak ac maximum.

SETTLING TIME: Less than 2 seconds to within 0.1% of final reading, except less than 4 seconds on the 1 mV range.

AS A DC AMMETER

RANGE	MAXIMUM READING	ACCURACY ±(% of rdg + % of rng)		SHUNT RESISTANCE	TEMPERATURE COEFFICIENT ±(% of rdg + % of rng)/°C		MAX. ALLOWABLE INPUT
10 nA	19.99 nA	0.3%	0.2%	1 MΩ	0.02%	0.02%	0.25 mA
100 nA	199.9 nA	0.2%	0.1%	100 kΩ	0.02%	0.01%	2.5 mA
1 μA	1.999 μA	0.2%	0.1%	10 kΩ	0.02%	0.01%	3 A*
10 μA	19.99 μA	0.2%	0.1%	1 kΩ	0.01%	0.01%	3 A*
100 μA	199.9 μA	0.2%	0.1%	100 Ω	0.01%	0.01%	3 A*
1 mA	1.999 mA	0.2%	0.1%	10 Ω	0.01%	0.01%	3 A*
10 mA	19.99 mA	0.2%	0.1%	1 Ω	0.01%	0.01%	3 A*
100 mA	199.9 mA	0.3%**	0.1%	0.1 Ω	0.01%	0.01%	3 A*
1000 mA	1999 mA	0.3%**	0.1%	0.1 Ω	0.01%	0.01%	3 A*

*Internally fused beyond 3 amperes. **Self-heating due to long-term measurement of greater than 1 ampere can cause 0.1% additional error.

NORMAL MODE REJECTION RATIO: Greater than 60 dB above one digit for a current of line frequency or twice line frequency.

AS AN OHMMETER

RANGE	MAXIMUM READING	ACCURACY ±(% of rdg + % of rng)		VOLTAGE ACROSS UNKNOWN* at full range	TEMPERATURE COEFFICIENT ±(% of rdg + % of rng)/°C		MAX. ALLOWABLE INPUT rms ac+dc
1 Ω	1.999 Ω	0.4%	0.1%	1 mV	0.04%	0.03%	250 V
10 Ω	19.99 Ω	0.3%	0.1%	10 mV	0.04%	0.01%	250 V
100 Ω	199.9 Ω	0.3%	0.1%	100 mV	0.04%	0.01%	250 V
1 kΩ	1.999 kΩ	0.3%	0.1%	100 mV	0.04%	0.01%	250 V
10 kΩ	19.99 kΩ	0.3%	0.1%	100 mV	0.04%	0.01%	250 V
100 kΩ	199.9 kΩ	0.3%	0.1%	100 mV	0.04%	0.01%	250 V
1 MΩ	1.999 MΩ	0.3%	0.1%	100 mV	0.04%	0.01%	250 V
10 MΩ	19.99 MΩ	0.3%	0.1%	100 mV	0.04%	0.01%	250 V
100 MΩ	199.9 MΩ	10.0%	0.1%	100 mV	0.3 %	0.01%	250 V
1000 MΩ	1999 MΩ	30.0%	0.1%	100 mV	1.0 %	0.01%	250 V

*0.6 volt maximum into an open circuit.

GENERAL

DISPLAY: 3 digits plus 1 overrange digit; decimal position, polarity, and overload indication; 5 readings per second. 3 least significant digits blank when overload condition exists, except on 1000-volt range.

ISOLATION: Lo to power line ground: greater than 1000 megohms shunted by less than 300 picofarads. Lo may be floated up to ±1200 volts with respect to power line ground.

ANALOG OUTPUT: ±1 volt dc at up to 1 milliampere for full range input, 100% overranging except on the 1000-volt range, where overranging is 20%.

OFFSET CURRENT: Less than 10 picoamperes.

WARMUP: 1/2 hour to complete stabilization.

ENVIRONMENT:

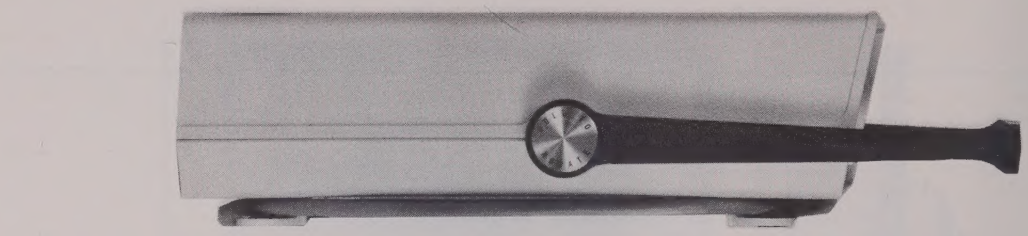
Operating: 10°C to 35°C, 0% to 80% relative humidity. 0°C to 10°C and 35°C to 50°C, 0% to 80% relative humidity within twice computed accuracy.

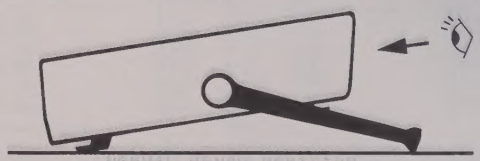
Storage: -25°C to 70°C, without batteries installed.
-25°C to 45°C, with batteries installed.

POWER: 90-110, 105-125, 195-235 or 210-250 volts (switch selected), 50-60 Hz, 5 watts. Optional rechargeable 6-hour battery pack.

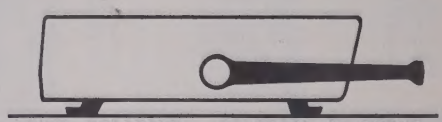
CONNECTORS: Input: binding posts. Analog Output: banana jacks.

DIMENSIONS, WEIGHT: Style K, 3-1/2 in. high x 9-1/4 in. wide x 10-3/4 in. deep (85 x 235 x 275 mm). Net weight, exclusive of batteries, 4 pounds (1,8 kg).

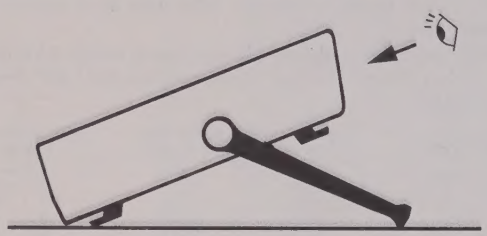


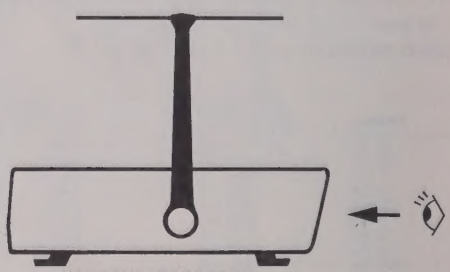


NORMAL BENCH POSITION

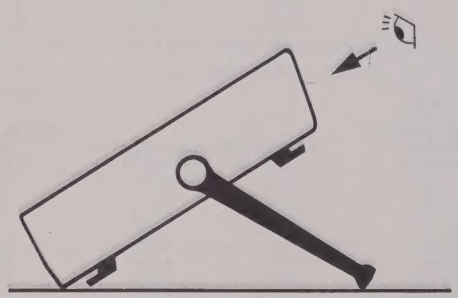


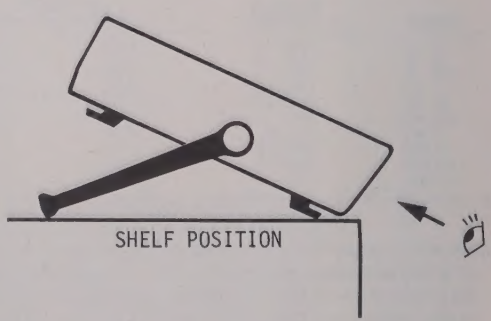
LEVEL POSITION - TILTBAIL AT FRONT



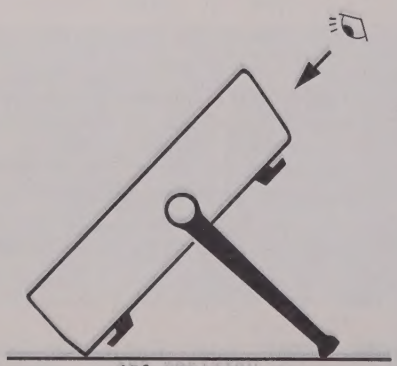


HANGING POSITION

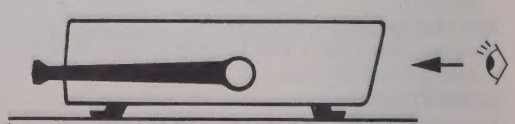




SHELF POSITION



45° POSITION



LEVEL POSITION - TILTBAIL AT REAR

FIGURE 2. Tilt Bail Positions.

SECTION 1. GENERAL INFORMATION

1-1. INTRODUCTION. The Model 160B is a wide-range digital multimeter capable of measuring voltage, current, and resistance. The Model 160B offers seven ranges of voltage from 1mV to 1000 volts, nine ranges of current from 10nA to 1000mA, and ten ranges of resistance from 1Ω to 1000MΩ. The Model 160B display is 3 digits plus 100% overrange.

1-2. FEATURES.

a. Voltage sensitivity to 1 microvolt per digit.

b. Current sensitivity to 0.01nA per digit.

c. Resistance sensitivity to 0.001Ω per digit.

d. Floating capability to ±1200 volts aboye case.

e. Built-in analog output.

f. Optional Model 1602B Digital Output.

g. Optional Model 1688A Rechargeable Battery Pack.

1-3. WARRANTY INFORMATION. The warranty is stated on the inside front cover of the manual. If there is a need for service, contact your Keithley representative or authorized repair facility as given in our catalog.

1-4. CHANGE NOTICE. Improvements or changes to the instrument not incorporated into the manual will be explained on a yellow change notice sheet attached to the inside back cover of the manual.

1-5. OPTIONAL MODEL 1602B DIGITAL OUTPUT. The Model 1602B is a field-installable digital output option which enables digital data recording and processing. The open-collector BCD outputs are TTL compatible.

1-6. OPTIONAL MODEL 1688A RECHARGEABLE BATTERY PACK. The Model 1688A is an accessory battery pack which enables either line or battery operation by use of the front panel Power Selector Switch. The Model 160B provides built-in recharging circuitry for use with the Model 1688A. The battery pack is field-installable in the Model 160B chassis.

FIGURE 3. Front Panel.

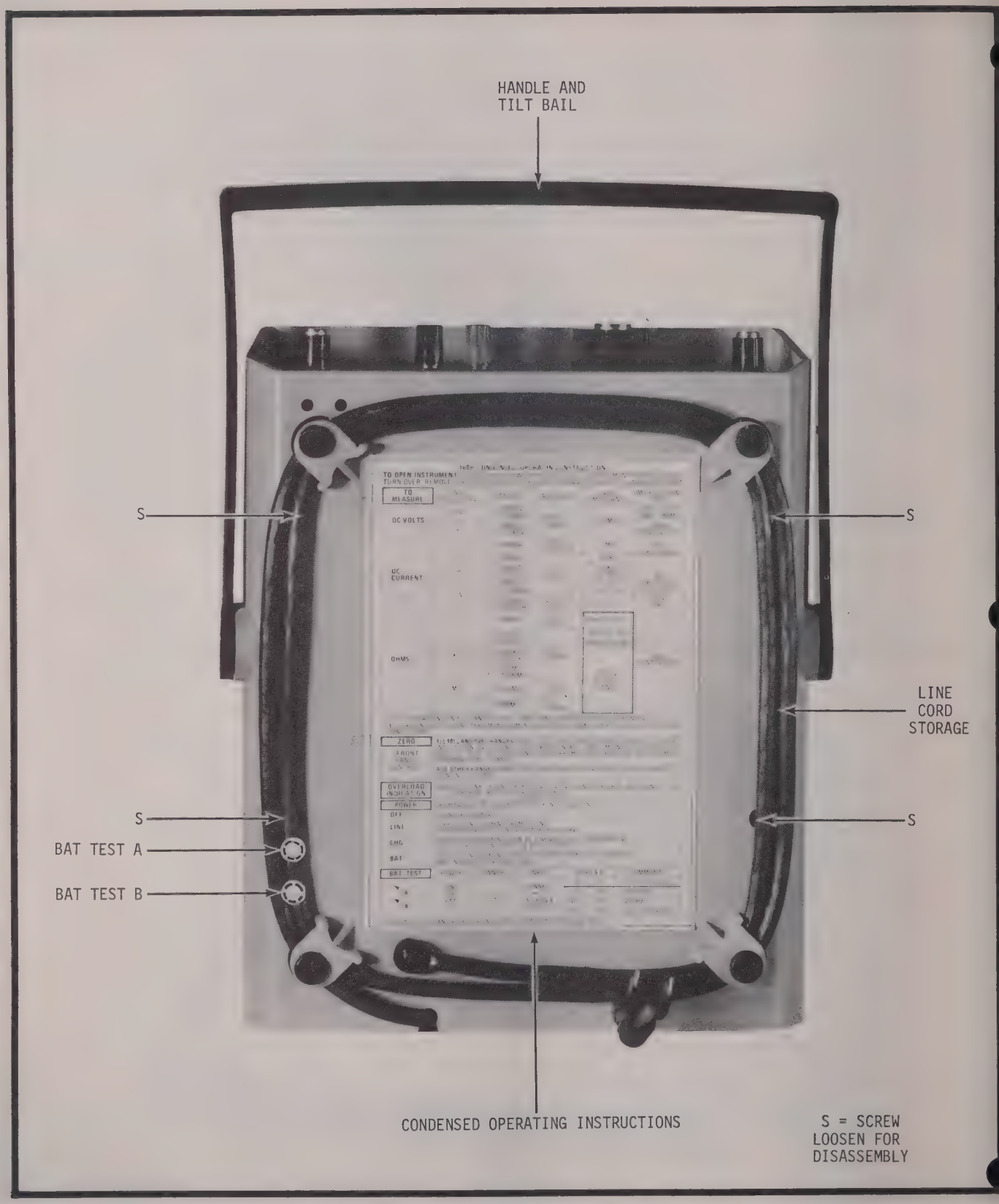
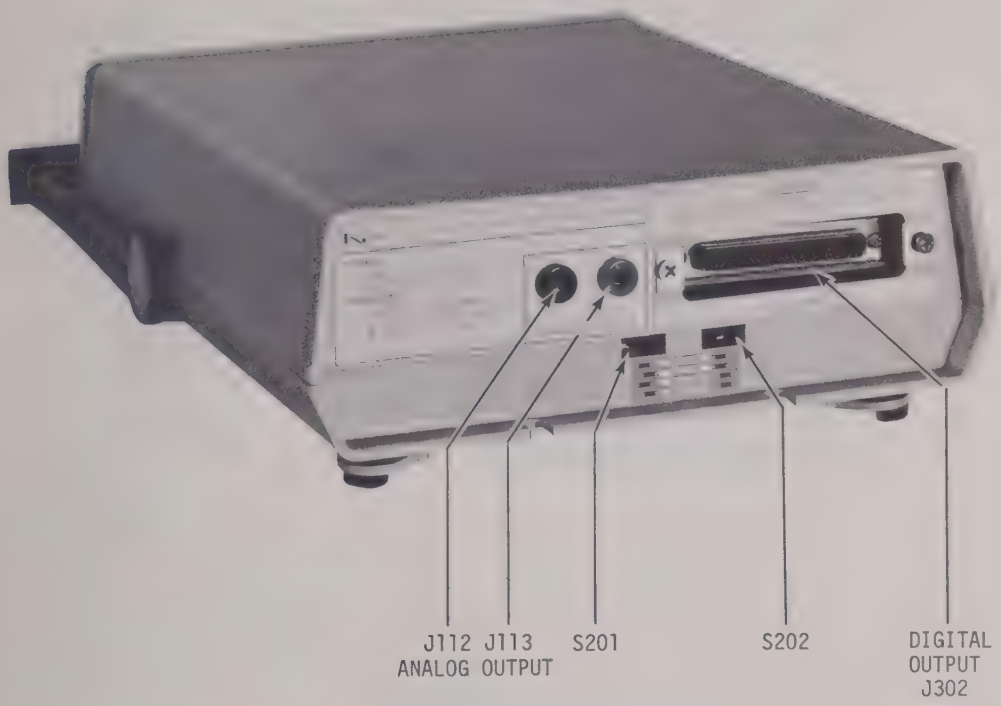
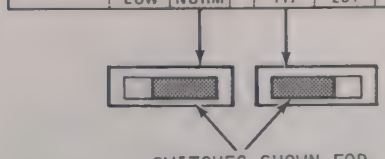


FIGURE 4. Bottom View Showing Line Cord.



LINE VOLTAGE	SWITCH SETTINGS		FUSES
90 - 110	LOW	117	3AG 1/8A SLO-BLOW INTERNAL 2 USED
105 - 125	NORM	117	
195 - 235	LOW	234	
210 - 250	NORM	234	

CAUTION: 234 VOLT LINE MAY CAUSE DAMAGE WITH 117V SELECTED.



SWITCHES SHOWN FOR
OPERATION FROM 105-125V LINE

FIGURE 5. Rear View Showing Line Switches.

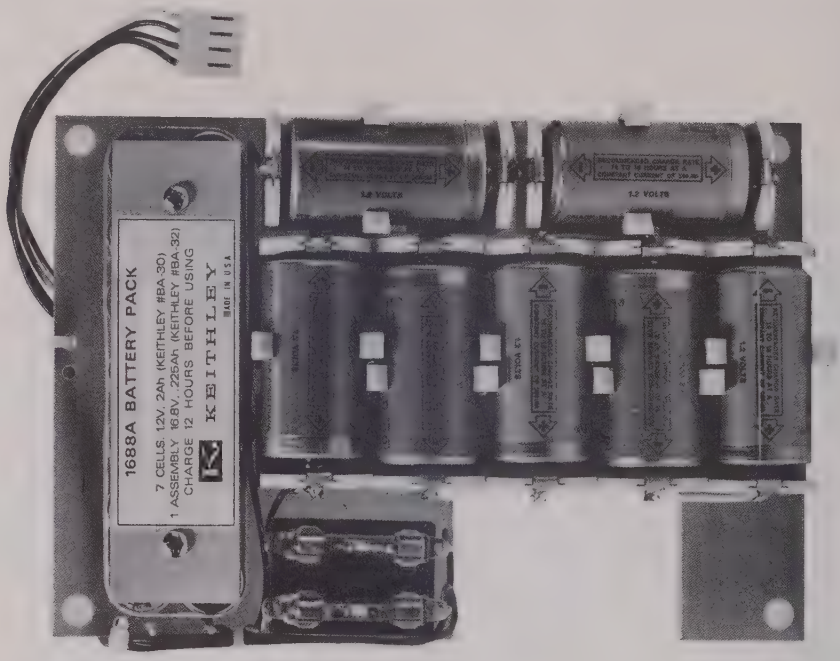


FIGURE 6. Model 1688A Rechargeable Battery Pack.

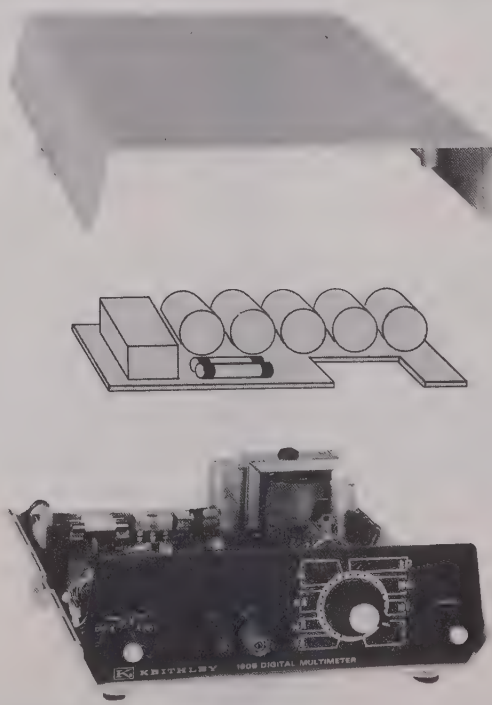
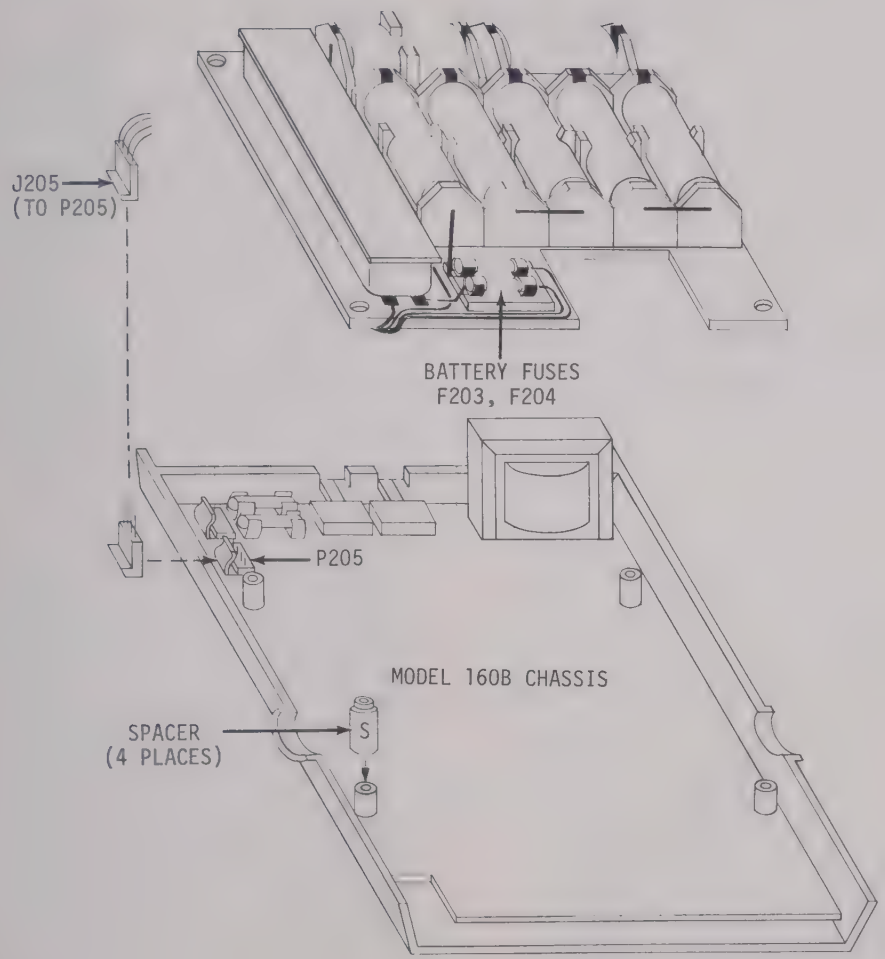


FIGURE 7. Exploded View of Model 160B/1688A.



CAUTION

DISCONNECT LINE CORD BEFORE OPENING
THE TOP AND BOTTOM COVER.
LINE VOLTAGE ON THE CHASSIS
REPRESENTS A SHOCK HAZARD.

FIGURE 8. Installation of Battery Pack.

SECTION 2. INITIAL PREPARATION

2-1. GENERAL. This section provides information needed for incoming inspection and preparation for use.

2-2. INSPECTION. The Model 160B was carefully inspected both mechanically and electrically before shipment. Upon receiving the instrument, check for any obvious damage which may have occurred during transit. Report any damages to the shipping agent. To verify the electrical specifications, follow the procedures given in Section 6.

2-3. PREPARATION FOR USE. The Model 160B is shipped ready-to-use. The instrument can be powered from line voltage or from rechargeable nickel-cadmium batteries (when the optional Model 1688A Rechargeable Battery Pack is installed).

a. How to Operate From Line Power. The Model 160B provides a three-wire cord which mates with third-wire grounded receptacles (see Figure 4 for plug configuration). The permanently installed line cord is stored by wrapping the cord around the base of the instrument as shown in Figure 4.

1. How to Set Line Switches. The Model 160B has two rear panel Line Switches which enable selection of line voltages over ranges from 90-110V, 105-125V, 195-235V, or 210-250V. To operate from line power, determine the appropriate line voltage range to be used and set the Line Switches as follows:

TABLE 2-1.
Summary of Line Switch Settings.

Range	Settings
90-110V	LOW, 117
105-125V	NORM, 117
195-235V	LOW, 234
210-250V	NORM, 234

For example, if the line voltage to be used is approximately 115 volts, select NORM and 117 which permits a range of operation from 105 to 125V. After Line Switches are set, connect the line cord and set the Power Switch to LINE.

2. Line Fuse Requirements. The Model 160B uses two line fuses to protect the line-operated power supply. The fuse types are 1/8 ampere, 3AB, slow-blow. Replace with Keithley Part No. FU-20.

3. How to Replace Fuses in Model 1688A. The Model 1688A uses 1 ampere fuses to protect the power supply regulators in case of malfunction. Fuses F203 and F204 are plug-in types and are located on pc board PC-349 as shown in Figure 8. Replace with 1 ampere, 3AB, slo-blo, Keithley Part No. FU-28.

b. How to Operate From Battery Power. To operate the Model 160B from batteries, the Model 1688A Rechargeable Battery Pack must be installed. The Model 1688A can be either field or factory installed. (The batteries in the Model 1688A may need recharging before their first usage to power the Model 160B.)

NOTE

The Model 1688A Rechargeable Battery Pack can be installed within the Model 160B chassis at any time. However, if the Model 1602B Digital Output is already installed, the Model 1688A cannot be used simultaneously.

1. How to Install Model 1688A Rechargeable Battery Pack. The batteries furnished with the Model 1688A come already installed in the battery pack. The battery pack includes 7 rechargeable "C" cells (1.2V, 3 AMP HR) and 1 rechargeable pack (16.8V). If batteries need to be replaced or re-installed, be certain to observe the proper polarity of individual cells as shown in Figure 6. To install the Model 1688A Battery Pack, turn the instrument over so that the bottom cover faces up. Loosen four slotted screws on the bottom cover as shown in Figure 4. (A chisel-blade screwdriver is required to loosen the slotted screws.) Turn over the instrument with top cover facing up, taking care to hold the top and bottom covers together. Carefully remove the top cover to gain access to the printed circuit board. (Two wires that connect to the Analog Output must be disconnected at the PC board before the top cover can be set aside.) Check to see that the four insulating spacers are in position on the printed circuit board. Place the Model 1688A Battery Pack in position on the spacers with the cable oriented as shown in Figure 8. Plug the 4-wire connector (J205) into the mating receptacle (P205) taking care to orient the connector as shown in Figure 8. After the Battery Pack is installed, replace the top cover. Turn over the instrument with bottom cover facing up and tighten down the four slotted-head screws.

TABLE 2-2.
Summary of Batteries Used in Model 1688A

Description	Quantity	Keithley Part No.
Rechargeable "C" cell, 1.2V, 2 AMP-HR	7	BA-30
Rechargeable battery pack, 16.8V, .225 AMP-HR	1	BA-32

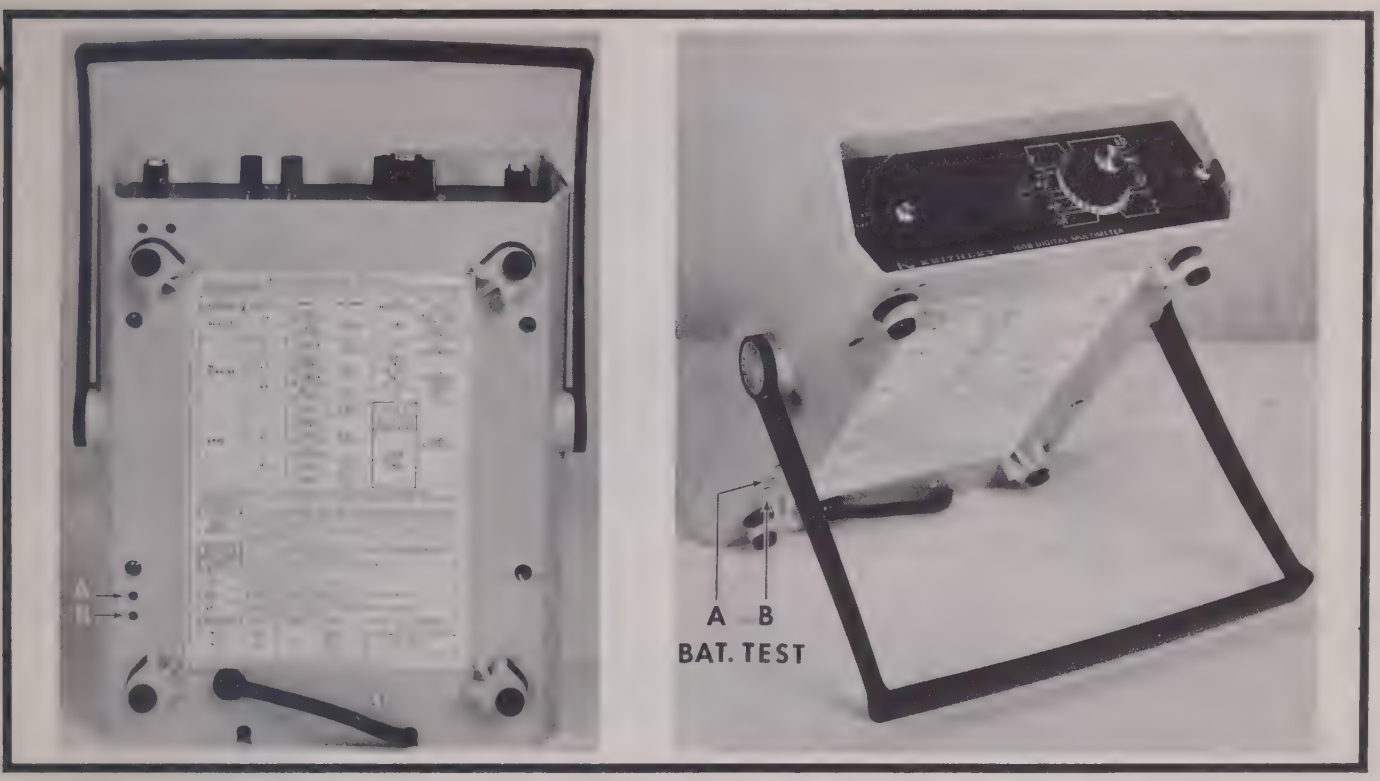


FIGURE 9. Battery Test Location.

2. How to Check Batteries. (Valid only in BAT mode). The Model 160B provides two test points (A and B) located on the bottom of the instrument as shown in Figure 9. These test points permit a convenient check of the condition of the internal Battery Pack without need to remove the Model 160B cover. The voltage at test points A or B may be measured using the Model 160B or any other comparable voltage measuring instrument. To check the voltages at test points A or B, select the BAT mode, connect the HI terminal of the Model 160B (for a self check) or other voltmeter to test points A or B and observe the measured voltage. (If a separate voltmeter is used, it is necessary to make a connection to the LO terminal of the Model 160B since both points A and B are to be referenced to circuit low.) Table 2-3 gives the battery voltages required at each test point.

TABLE 2-3.
Summary of Battery Voltage Levels (BAT mode)

Test Point	Acceptable Battery Levels Range	Normal	Recharge if below	Battery Tested
A	2.5V - 9V	4.8V	2.5V	BA-32
B	7V - 10.5V	8.4V	7V	BA-30

3. How to Charge Batteries. The Model 160B provides built-in recharging circuitry for recharging the Model 1688A Battery Pack. To recharge the internal batteries, connect the Model 160B to line power and select the CHG position. Recharging time is dependent on the condition of the batteries at the time of recharge. Typically, the recharge time is 1-1/2 hours per hour of discharge (or 9 hours of charging time for every 6 hours of operating time in the battery mode).

IMPORTANT

The instrument must be operated in the BAT mode in order to obtain a valid battery condition at test points A and B. This will ensure that the batteries are supplying power to the instrument. If the voltages are measured when the Model 160B is operated in the LINE mode a different reading may be observed since the batteries are not connected and therefore do not supply power to the instrument.

CAUTION

Overcharging the batteries will raise the internal temperature of the instrument and may also shorten the life of the batteries.

NOTE

The Model 160B may be operated while in the CHG mode. However, if the Battery Pack is not installed, the Model 160B will not be operable when the CHG mode is selected since the batteries are connected in series with the line power supply.

SECTION 3. OPERATING INSTRUCTIONS

3-1. GENERAL. This section provides information needed to operate the Model 160B for measurement of voltage, current, and resistance.

3-2. HOW TO SELECT POWER. The Model 160B may be powered from line voltage or rechargeable nickel-cadmium batteries (when the Model 1688A is installed). The Model 160B has a built-in line-voltage power supply and line cord. If the accessory Model 1604 Rechargeable Battery Set is ordered and installed, then the user has the option of selecting line or battery operation via the front panel rotary power switch.

NOTE

The accessory Model 1688A Rechargeable Battery Set may be ordered at the time of purchase of the Model 160B or may be purchased and field installed at a later time if so desired. The Model 1688A features plug-in wiring. As a result, no modifications need to be made to the Model 160B chassis.

a. How to Operate from Line Power. The Model 160B can be powered from Line voltage over four ranges from a minimum of 90V to a maximum of 250V. See Table 2-1.

1. Set rear panel Line Switches to appropriate positions as shown in Figure 5.

2. Plug line cord into source of line power.

3. Set front panel Power Switch to LINE.

b. How to Operate from Battery Power.

1. Install Model 1688A Rechargeable Battery Pack.

2. Check battery voltages at Test Points A and B to ensure that batteries are charged sufficiently.

3. If necessary, plug line cord into ac power and set Power Switch to CHG to bring battery voltage up to useable levels.

4. When battery level is sufficient, disconnect line cord and set Power Switch to BAT.

3-3. HOW TO MAKE INPUT CONNECTIONS. The Model 160B has two front panel terminals identified as "HI" (red) and "LO" (black). These terminals accomodate banana plugs, alligator clips, spade lugs, bare wires, and other similar input connections. Leads may be fabricated using a good quality copper wire terminated by single banana plugs such as Keithley Part No. BG-5 or dual banana plug such as Keithley Part No. BG-7. Ready-made test leads are also available from Keithley. Accessory Model 1681 Clip-on Test Lead Set includes two 40 inch long leads terminated by a banana plug and spring-loaded clip which easily attaches to wires and terminals on pc boards, etc. Model 1683 Universal Test Lead Kit features interchangeable probe tips for various applications. The Kit includes regular probes, alligator clips, banana plugs, spade lugs, and phone tips. All-copper leads and terminations are best for measurements on the 1mV and 1Ω ranges.

3-4. HOW TO SELECT FUNCTION. Function is selected by means of a single front panel Range Switch. The Range dial is marked in "engineering" units for measurement of voltage (mV, V), current (nA, μA, mA), and resistance (Ω, kΩ, MΩ). For each function, rotating the knob clockwise causes the Model 160B to switch to a less sensitive range.

a. DC Voltage. The voltage sectors of the Range Switch are designated in millivolts (mV) and volts (V) for full ranges from 1mV to 1000V. A full stop at the 1000 volt range prevents inadvertant switching to the nanoampere ranges by clockwise rotation.

b. Resistance. The resistance sectors of the Range Switch are designated in ohms (Ω), kilohms (kΩ), and megohms (MΩ) for full ranges from 1 ohm to 1000 megohms.

c. Current. The current sectors of the Range Switch are designated in nanoamperes (nA), microamperes (μA), and milliamperes (mA) for full ranges from 10 nanoamperes to 1000 milliamperes.

TABLE 3-1.
Summary of Operation in LINE, CHG, and BAT Modes.

Switch Position	Condition of Instrument: Line Connected 1688A not installed	Line connected 1688A installed	Line not connected 1688A installed
OFF	OFF	OFF	OFF
LINE	ON	ON	OFF
CHG	OFF	ON	OFF
BAT	OFF	ON	ON

FIGURE 10. Front Panel Controls.

3-5. HOW TO MEASURE VOLTAGE. The Model 160B measures dc voltage in seven ranges: 1mV, 10mV, 100mV, 1V, 10V, 100V, and 1000V. Maximum dc input is 1200V dc + peak ac.

a. How to Select Range. Function and range is selected by rotating the Range Switch to the appropriate position. Three positions are direct-reading in millivolts (mV); four positions are direct-reading in volts (V). Decimal point is selected by the Range Switch. Polarity is automatically displayed. If the input signal exceeds twice full range, the display blanks (3 least significant digits) to indicate an "overrange" condition.

TABLE 3-2.
Voltage Ranges Displayed

Range Setting	Max. Display	Units
1000 V	1999 *	V
100 V	199.9	V
10 V	19.99	V
1 V	1.999	V
100 mV	199.9	mV
10 mV	19.99	mV
1 mV	1.999	mV

*Maximum allowable input is 1200V dc plus peak ac even though display can be read beyond 1200V.

b. How to Determine Accuracy. The Model 160B accuracy is ±0.1% of reading ± 1 digit. For example, a display reading of 1.000 volt dc will have an uncertainty of ±0.1% ± 1 digit or ±.002 volts. The input resistance in the dc mode is 10 megohms. Measurements from relatively high source resistances could cause an additional reading error. The amount of error due to loading can be determined by the following relationship:

$$\% \text{ error} = 100 \times R_S \div (R_S + 10^7)$$

where R_S = source resistance in ohms.

For example, a source resistance of 10,000 ohms will result in a loading error of approximately 0.1% of reading.

NOTE

The input current of the 160B can also cause reading errors on the most sensitive voltage ranges when high source resistances are present. For example, an input current of 10pA and a source resistance of 1MΩ produce an error voltage of 10μV.

c. Maximum Allowable Input. The maximum input to the Model 160B is 1200V dc + peak ac. On 1mV, 10mV, and 100mV ranges, the maximum continuous input is 600V (1200V momentary) dc + peak ac. The Model 160B can display dc voltages greater than ±1200V but damage to the input is possible.

IMPORTANT

The Model 160B provides ac rejection (NMRR) of greater than 60 dB on the highest range. However, a large ac signal superimposed on a dc level could cause damage if the input to the Model 160B exceeds 1200 volts dc + peak ac.

d. How to Zero the Display. To accurately zero the instrument, place a low-thermal short (such as a piece of clean copper wire) across the input terminals, set the Range Switch to the 1mV range, and adjust the front panel Zero control for a flashing "±" sign at the display. The display should then read ±.000, with some flicker of the least significant digit due to noise and A-D converter uncertainty.

Once the zero has been set accurately, there should be little reason to rezero the instrument again soon when making measurements on the 10mV through 1000V ranges. The time stability of the zero setting is excellent, and in applications requiring continuous operation of the Model 160B, the zero setting will hold for months. The front panel Zero control is convenient when making measurements on the 1mV Range.

A test set-up and cables when connected to the 160B may cause offset voltages because of thermoelectric effects (See Section 3-9). These offset voltages might be only a few microvolts or several tens of microvolts. In such situations, the Zero control can be used to buck out any initial offsets. Low thermal cabling and connections should be used whenever possible. The instrument zero can also be checked, and adjusted, by shorting the input on any range (voltage, current, or resistance). The Zero control will have varying effects on the different ranges depending on the sensitivity of the input amplifier, but the zero control can be used in this manner. Again, it should be emphasized, that for most measurements with the Model 160B, the Zero control can be set once and then left untouched. (See also Section 3-6c "Low Ohms Zeroing").

NOTE

With the input open on the 1mV Range, the Model 160B display may show a reading as high as ±.100. This is equivalent to an offset current of 10.0pA. If the display shows a reading greater than ±.100, then the internal potentiometer, R121, should be readjusted. Typically, the offset current will be less than 5pA.

e. How to Use Model 1601 AC/DC Probe. To make ac measurements, connect the Model 1601 accessory AC/DC Probe to the Model 160B input terminals. Set the Range to desired voltage range. Set switch on probe to AC. Use the probe tip plus ground clip to make connections to circuit under test. See Section 5 for complete specifications.

f. How to Use Model 1682 RF Probe. To make rf ac measurements, connect the Model 1682 Probe to the Model 160B input terminals. Set the Range to desired voltage range. Maximum allowable input is 30V rms ac, 200V dc.

3-6. HOW TO MEASURE RESISTANCE. The Model 160B measures resistance in 10 ranges: 1Ω, 10Ω, 100Ω, 1kΩ, 10kΩ, 100kΩ, 1MΩ, 10MΩ, 100MΩ, and 1000MΩ.

a. How to Select Range. Function and range is selected by rotating the Range Switch to the appropriate position. Three positions are direct-reading in ohms (Ω); three positions are direct-reading in kilohms (kΩ); four positions are direct-reading in megohms (MΩ). Decimal point is selected by Range Switch. If the input signal exceeds twice full range the display blanks to indicate an "overrange" condition.

TABLE 3-3.
Resistance Current Ranges

Range Setting	Max. Display	Units	Impressed Current
1 Ω	1.999	Ω	1 mA
10 Ω	19.99	Ω	1 mA
100 Ω	199.9	Ω	1 mA
1 kΩ	1.999	kΩ	100 µA
10 kΩ	19.99	kΩ	10 µA
100 kΩ	199.9	kΩ	1 µA
1 MΩ	1.999	MΩ	100 nA
10 MΩ	19.99	MΩ	10 nA
100 MΩ	199.9	MΩ	1 nA
1000 MΩ	1999	MΩ	0.1 nA

b. How to Determine Accuracy. The accuracy of the Model 160B is specified in terms of a percent of reading and a percent of range. For example, a display of 1.000 kilohm (kΩ) will have an uncertainty of ±0.004kΩ.

c. How to Measure "LOW" ohms. When making measurements on the 1Ω, 10Ω, and 100Ω ranges, the Model 160B is to be zeroed on the 1Ω range. The zeroing is accomplished by shorting the test leads together, and adjusting the display for a flashing + and -.000Ω. By zeroing the instrument in this manner, lead resistance of 200 milliohms (minimum) can be compensated for. The instrument must be rezeroed on the 1Ω range each time a different set of test leads is used. Before making measurements right at the input terminals (no test leads used), the instrument should be zeroed on the 1Ω Range after placing a short, such as a piece of copper wire, across the binding posts. Copper leads and clips are best for making measurements on the 1Ω Range, because the voltage drop across a 1Ω resistor is only 1mV.

CAUTION

Care should be taken when making resistance measurements in circuits which may have voltages on capacitors, etc. or where line voltage is present. Although the Model 160B is fully protected against accidental voltages up to 250V rms in resistance function, if higher voltages are applied, damage may occur.

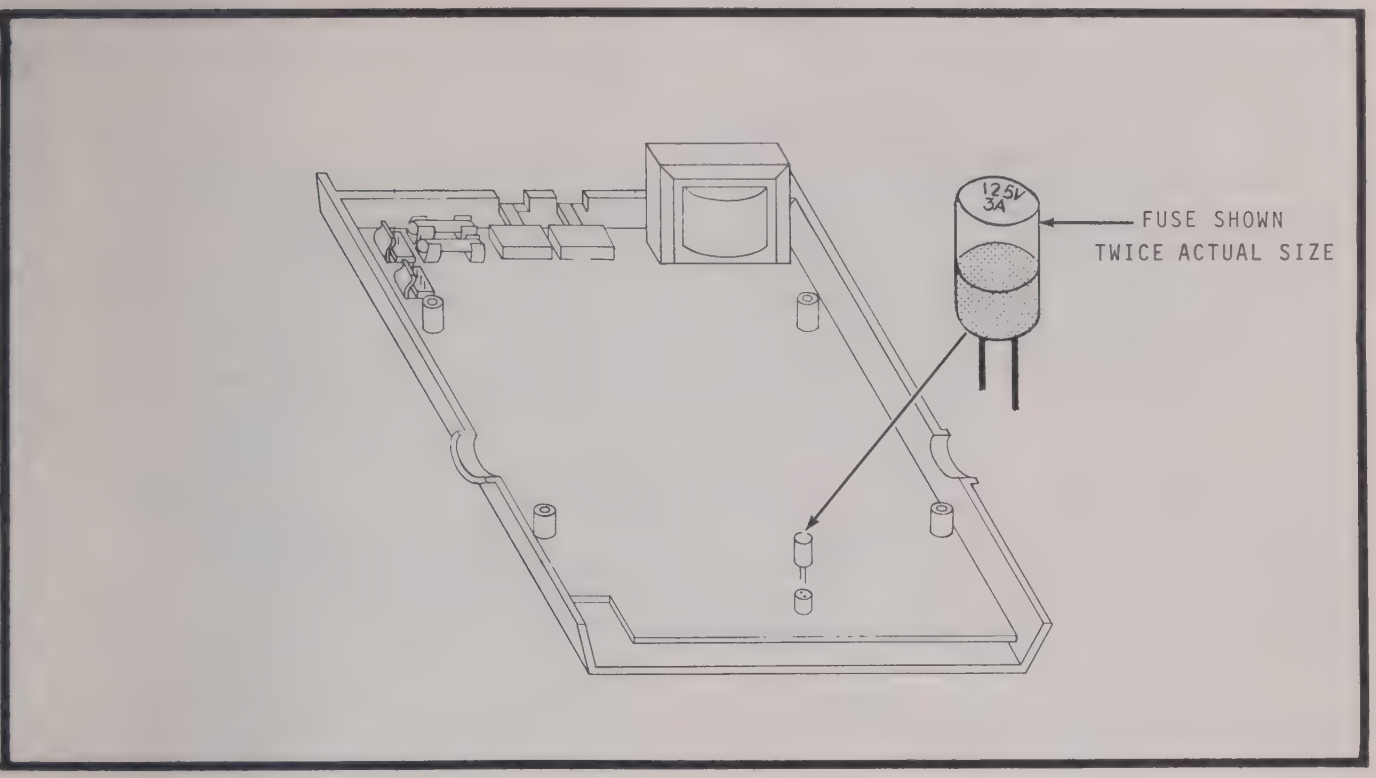


FIGURE 11. Location of Protection Fuse.

3-7. HOW TO MEASURE CURRENT. The Model 160B measures dc current in nine ranges: 10nA, 100nA, 1μA, 10μA, 100μA, 1mA, 10mA, 100mA, and 1000mA.

a. How to Select Range. Function and range is selected by rotating the Range Switch to the appropriate position. Two positions are direct-reading in nanoamperes (nA); three positions are direct-reading in microamperes (μA); four positions are direct-reading in milliamperes (mA). Decimal point is selected by range switch. Polarity is automatically displayed. If the input signal exceeds twice full range, the display blanks to indicate an "overrange" condition.

TABLE 3-4.
Current Ranges Displayed

Range Setting	Max. Display	Units	Shunt R*
10 nA	19.99	nA	$10^6\Omega$
100 nA	199.9	nA	$10^5\Omega$
1 μA	1.999	μA	$10^4\Omega$
10 μA	19.99	μA	$10^3\Omega$
100 μA	199.9	μA	$10^2\Omega$
1 mA	1.999	mA	10 Ω
10 mA	19.99	mA	1 Ω
100 mA	199.9	mA	0.1 Ω
1000 mA	1999	mA	0.1 Ω

*Internal wiring resistance can add approx. 0.1Ω to all values of shunt resistance. For example, on the 1000mA Range, the total resistance between the HI and LO input terminals of the Model 160B could be approx. 0.2Ω.

b. How to Determine Accuracy. The accuracy of the Model 160B is specified in terms of a percent of reading and a percent of range. For example, a display of 1.000 milliampere (mA) will have an uncertainty of ±0.003mA. An additional reading error should be considered if the source resistance is not greater than 1000 times the shunt resistor. For example, on the 1mA range, a source resistance of 1000 ohms would result in a loading error of approximately 1% of reading. Loading error for other source resistances can be determined by the following relationship:

$$\% \text{ error} = \frac{100 \times \text{Shunt Resistance}}{\text{Shunt Resistance} + \text{Source Resistance}}$$

c. How to Determine Maximum Allowable Input. On the 10nA and 100nA ranges, the maximum input is 250 volts. On 1μA and higher ranges, the Model 160B is internally fused beyond three amperes. An input protection circuit limits the voltage applied to the shunt resistor to approximately 1.5 volts, thereby reducing the possibility of over-heating the resistor.

1. How to Check Current Fuse. Select 1000mA range. Verify input resistance of less than 1 ohm. If greater than 1 ohm, replace fuse. (Keithley FU-43).

2. How to Replace Current Fuse. The current fuse (F101) is located on the printed circuit board PC-349 and is installed in a socket. The fuse is accessible by removing the top cover. See Figure 11. An accessory fuse is furnished with each instrument. Fuse rating is 3 amperes.

d. How to Use the Model 1651 Current Shunt (for measurements to 50A). Current measurement capability of the Model 160B may be extended to 50 amperes through the use of accessory Model 1651 50-Ampere Shunt. The Model 1651 permits 4-terminal connections to minimize measurement error due to lead resistance. To use the Model 1651, connect the voltage sensing leads to the Model 160B input terminals. Connect separate current leads (not furnished) between the source and the large hex-head bolts on the Model 1651. The current leads should be rated for currents up to 50 amperes. The shunt resistance is 0.001 ohm, which produces a sensitivity of 1mV/Amp. As examples, 10 amps current results in a 10mV drop on 10mV RANGE, and 30 amps yields a voltage drop of 30mV which can be read on the 100mV RANGE. Power dissipated in the shunt is 2.5 watts at 50 amperes.

3-8. NOISE CONSIDERATIONS. The limit of resolution in voltage and current measurements is determined largely by the noise generated in the source. Stray low-level noise is present in some form in nearly all electrical circuits. The instrument does not distinguish between stray and signal voltages since it measures the net voltage. When using the 1mV and 10mV ranges, consider the presence of low-level electrical phenomena such as thermocouples (thermoelectric effect), flexing of coaxial cables (triboelectric effect), apparent residual charges on capacitors (dielectric absorption), and battery action of two terminals (galvanic action).

3-9. THERMAL EMFS. Thermal emfs (thermoelectric potentials) are generated by thermal differences between two junctions of dissimilar metals. To minimize the drift caused by thermal emfs, use copper leads to connect the circuit to the instrument. The front panel ZERO control can be used to buck out a constant thermal offset voltage if necessary. The Keithley accessory Model 1483 Low Thermal Connection Kit contains all necessary materials for making very low thermal copper crimp connections for minimizing thermal effects.

3-10. MAGNETIC FIELDS. The presence of strong magnetic fields can be a potential source of ac noise. Magnetic flux lines which cut a conductor can produce large a-c noise especially at power line frequencies. The voltage induced due to magnetic flux is proportional to the area enclosed by the circuit as well as the rate of change of magnetic flux. For example, the motion of a 3-inch diameter loop in the earth's magnetic field will induce a signal of several tenths of a microvolt. One way to minimize magnetic pickup is to arrange all wiring so that the loop area enclosed is as small as possible (such as twisting input leads). A second way to minimize magnetic pickup is to use shielding as described in Section 3-12.

3-11. AC ELECTRIC FIELDS. The presence of electric fields generated by power lines or other sources can have an effect on instrument operation. AC voltages which are very large with respect to the full-range sensitivity could drive the input amplifier into saturation, thus producing an erroneous DC output. At line frequency or twice line frequency, the instrument is capable of rejecting AC voltages whose peak-to-peak amplitude is equal to the full-range DC sensitivity on the 100mV through 1000V ranges. This level of interfering AC signal will produce no more than 1 digit error. On the 1mV and 10mV Ranges, the instrument can reject line frequency and twice line frequency signals whose p-p amplitude is equal to 10 times the full-range sensitivity. For example, on the 1mV Range, a 10mV p-p, 50 Hz signal will produce no more than 1μV (1 digit) DC error. Peak-to-peak AC voltages greater than 1X the full-range sensitivity on the 100mV through 1000V ranges, the 10X the full-range sensitivity on the 1mV and 10mV ranges will cause clipping in the AC section of the Model 160B input amplifier. For this reason, shielding is recommended when making sensitive DC voltage measurements, or when making measurements from high source impedances. (See Shielding, Section 3-12.) The instrument is also capable of rejecting frequencies other than power line frequencies. There is one problem to consider; however, the input amplifier of the Model 160B uses a modulator to convert DC signals to AC signals before amplification. The drive frequency of this modulator is 220 Hz nominally, ± approx. 5%. Interfering AC signals with frequencies equal to the modulator drive frequency, or multiples thereof, will appear as modulated DC, and produce large DC errors.

3-12. SHIELDING.

a. Electric Fields. Shielding is usually necessary when the instrument is in the presence of very large a-c fields or when very sensitive measurements are being made. The shields of the measurement circuit and leads should be connected together to ground at only one point. This provides a "tree" configuration, which minimizes ground loops.

b. Magnetic Fields. Magnetic shielding is useful where very large magnetic fields are present. Shielding, which is available in the form of plates, foil or cables, can be used to shield the measuring circuit, the lead wires, or the instrument itself.

c. Other Considerations.

1. Voltmeter Measurements. Use shielded input leads when source resistances are greater than 1 kilohm or when long input cables are used.

2. Current Measurements. On the mA and μA current ranges, no special shielding precautions need be taken. However, on the 100 and 10 nanoampere ranges, shielded input leads are recommended.

3. Resistance Measurements. Shielding of input leads and source are recommended for measurements on the 10 megohm through 1000 megohm ranges to prevent erroneous readings.

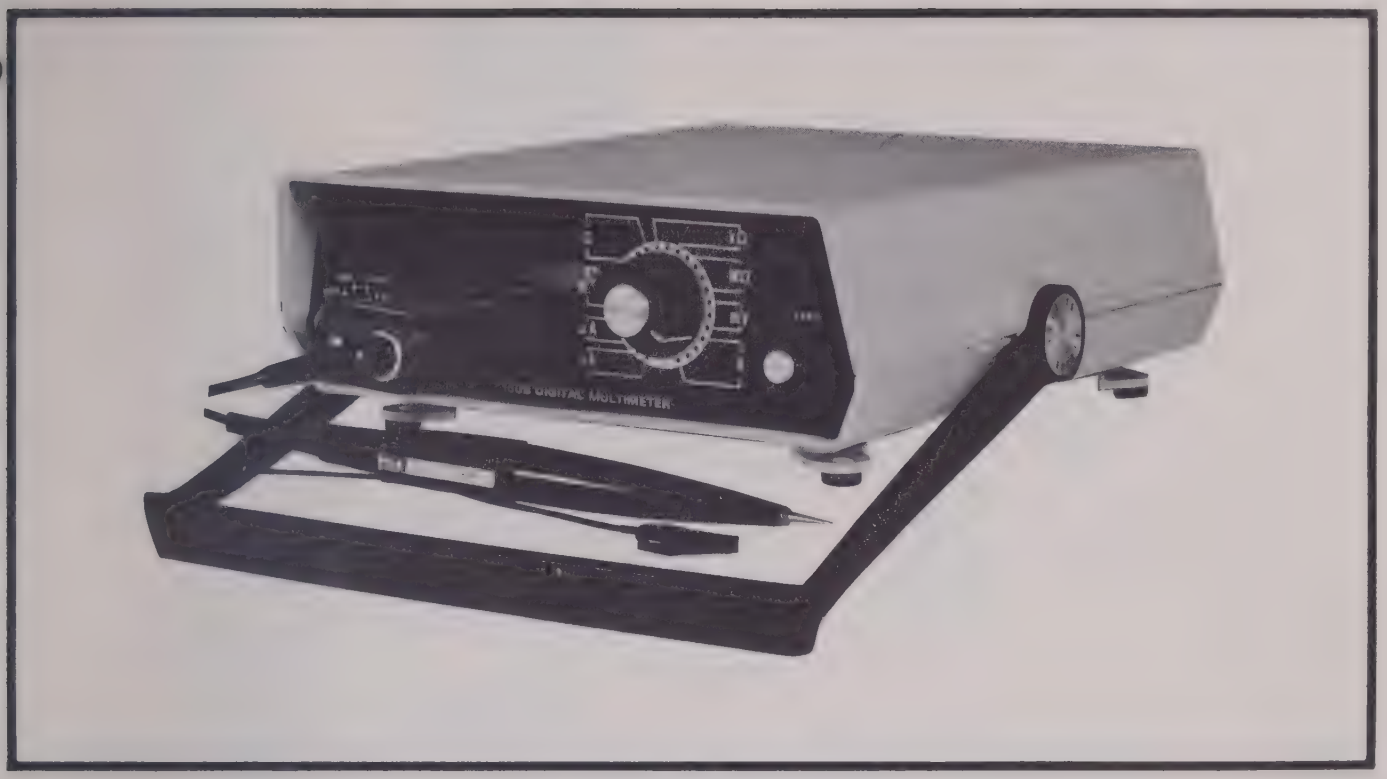


FIGURE 12. Voltage Measurements Using Model 1601 AC/DC Probe.

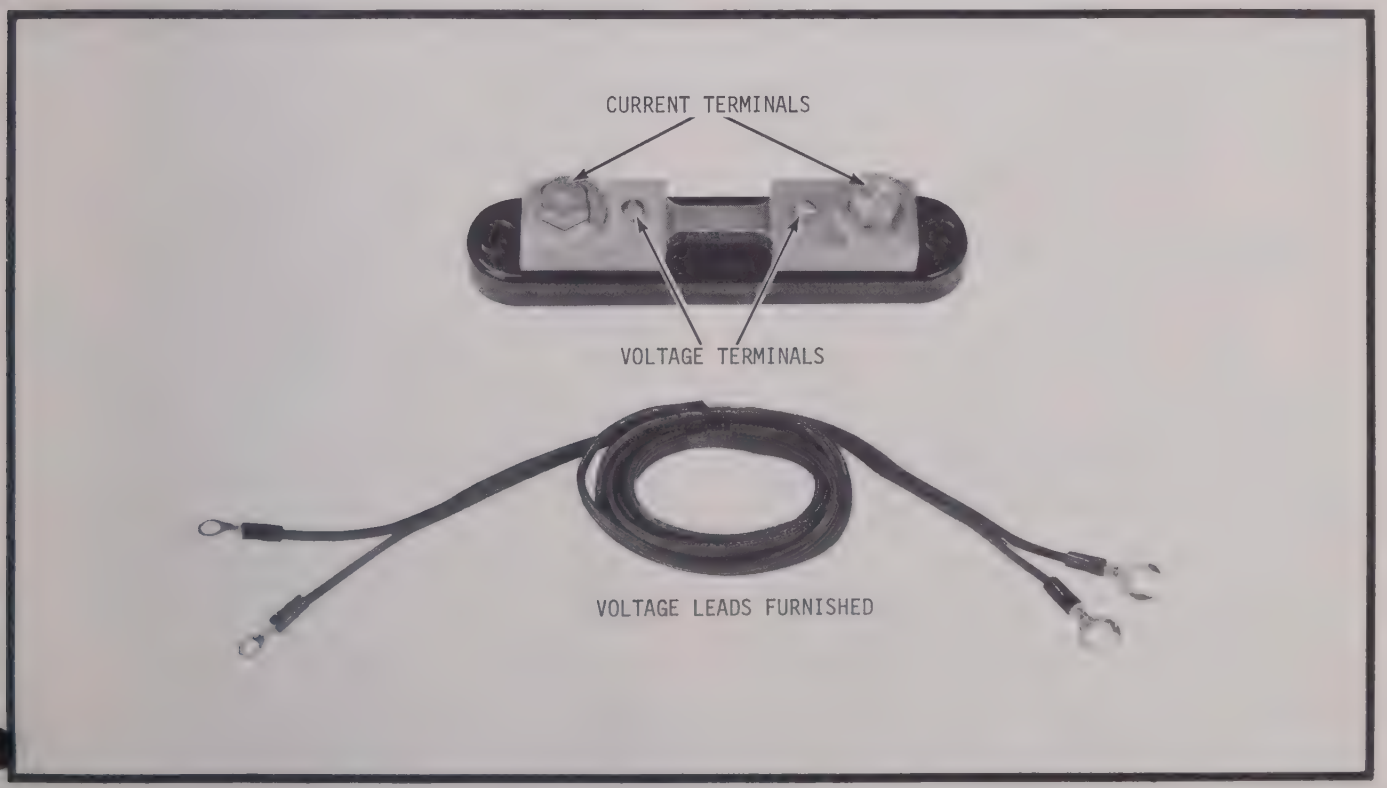


FIGURE 13. Current Measurements Using Model 1651 Shunt.

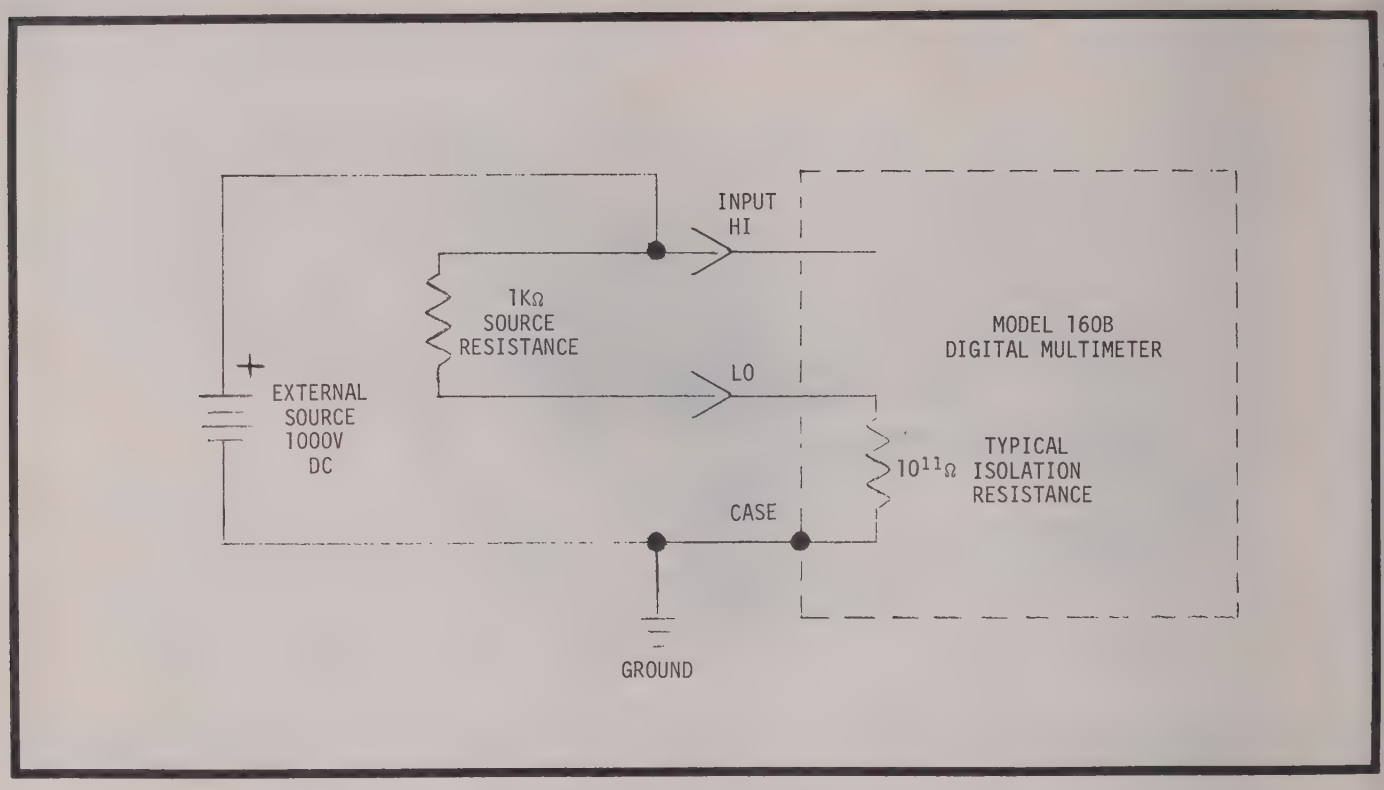


FIGURE 14. Floating Operation.

3-13. HOW TO USE THE ANALOG OUTPUT. The Model 160B has an analog output of ±1 volt at full-range (non-inverting) at up to 1 milliampere (2mA at 2 volts) for recording or monitoring purposes. Also, the analog output enables the Model 160B to be used as a low-noise, low drift DC amplifier.

TABLE 3-5.
Gain at ANALOG OUTPUT

Range	Gain	Full Range Output
1 mV	X1000	1V
10 mV	X100	1V
100 mV	X10	1V

For off-ground operation, the analog output should be connected only to equipment capable of operating off-ground also. The low side of the analog output is at the same potential as the "LO" input terminal of the Model 160B.

3-14. HOW TO USE MODEL 160B OFF-GROUND. The "LO" terminal can be operated off ground at potentials of up to ±1200V. Isolation from the "LO" terminal to power line ground is specified at 1000MΩ, or $10^9\Omega$ (shunted by 300pF). Typically, the isolation resistance from LO to GND is two decades greater than $10^9\Omega$ ($10^{11}\Omega$). Because of this excellent isolation, operating the Model 160B off ground results in very little loading (from LO to GND) of a floating source. At 1000V above ground, the Model 160B will require, typically, only 10nA from the source. The excellent isolation also accounts for the high common-mode rejection ratio of the Model 160B. Even with the "HI" terminal driven and a source resistance of 1kΩ, 1000 VDC (from HI to GND) will produce typically only 10μV DC error. This error voltage is determined directly from the ratio of the source resistance to the "isolation" resistance (See Figure 14).

$$I \simeq \frac{1000V}{10^{11}\Omega} = 10^{-8}A$$

$$V_{\text{across 1k}} = I \times 1k\Omega = 10^{-8} \times 10^{3} = 10\mu VDC$$

The "isolation" capacitance from LO to GND is important when AC common-mode signals are present. In the Model 160B, this capacitance is specified at 300 pF maximum. At a frequency of 60 Hz, 300 picofarads has a reactance of approximately 10MΩ. With the HI terminal driven and a source impedance of 1kΩ, a 1000V p-p, 60 Hz, common-mode signal will produce a voltage of only 100mV p-p across the Model 160B input terminals. This 100mV p-p signal will be further rejected by the input amplifier and A-D converter so that the total rejection at the digital display is at least 140 dB. At lower levels of AC common-mode signals, the total rejection at the display is even greater. For example, a 60 Hz, 100V p-p signal should produce only about 1 digit error on the 1mV Range for a total rejection of approx. 160 dB. (HI driven, 1kΩ source impedance.) With both AC and DC common-mode signals, rejection is much greater than specified when the Model 160B LO terminal is driven, rather than the HI terminal. Where there is a need for even greater isolation from LO to power line ground, or where there is a need to float at potentials greater than 1200 volts above power line ground the Model 1688A Battery Pack should be used.

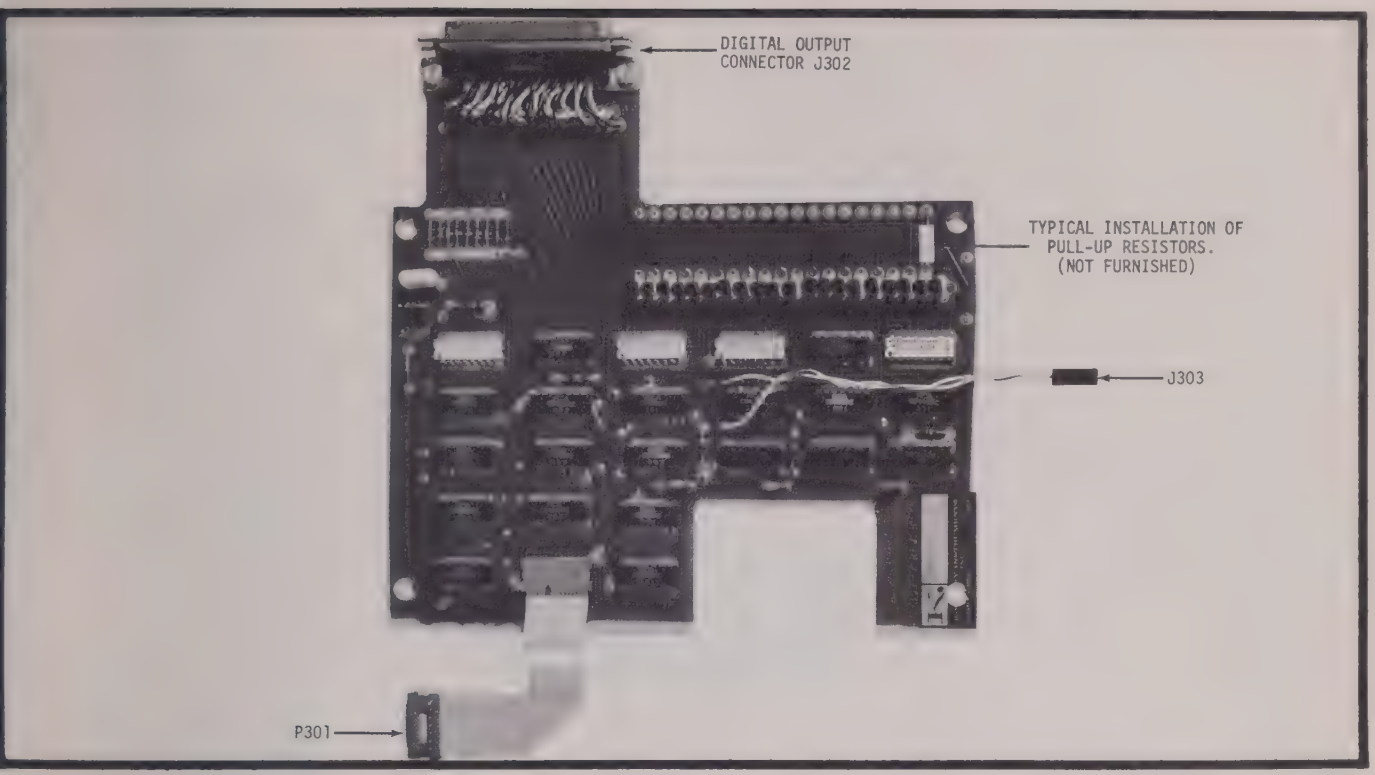


FIGURE 15. Model 1602B Digital Output.

TABLE 3-6.
Specifications for Model 1602B Digital Output.

DIGITAL OUTPUT: BCD open collector positive logic represents each of 3 digits, overrange digit, overload, decimal position, and polarity.
FLAG (FLAG): Present for approximately 200 milliseconds during each conversion. No change in Digital Output is made during this interval.
OUTPUT LOGIC LEVELS:
Output logic "1" ≡ open collector to output LO.
Output logic "0" ≡ closure to output LO.
Output Device: 2N5089 or equivalent (greater than 25-volt breakdown, less than 0.5 volt while sinking +15 milliamperes).
REMOTE CONTROLS:
Strobe: 6 lines for serializing in multiples of 4 bits. Logic "1" inhibits controlled output lines.
Output Hold: Logic "0" retains data from last reading at Digital Output.
Display Hold: Logic "0" retains data from last reading (escept for polarity and decimal) at Digital Output and Display.
FLAG/$\overline{\text{FLAG}}$ Reset: Transition from logic "1" to logic "0" resets FLAG and $\overline{\text{FLAG}}$ for remainder of conversion in process.
CONTROL LOGIC LEVELS:
Logic "1" ≡ either an open circuit or a voltage between +3.5 and +15 volts referenced to output LO.
Logic "0" ≡ closure to output LO within 0.8 volt while sinking +1 milliampere.
PRINT RATE: 5 readings per second.
ENVIRONMENT:
Operating: 0°C to 50°C, 0% to 80% relative humidity.
Storage: -25°C to 70°C.
CONNECTOR: Output: AMP205209-1
DIMENSIONS, WEIGHT: Mounts inside 160B. Field installable with screwdriver. Adds 0.5 pounds (0,3 kg) to 160B.
POWER: Obtained from 160B. Consumes negligible power.
ACCESSORIES SUPPLIED: Output mating connector and hood.

WARNING

The Model 1602B Digital Output is not isolated from the 160B input high and low. If the Model 1602B Digital Output is installed the digital input/output lines will float at the same potential of the Model 160B input high and low. Any equipment connected to the Model 1602B must also float. Hazardous voltages could be present at the digital output lines if the Model 160B is floated above safety ground. The Model 1602B must never be grounded while the Model 160B is floated.

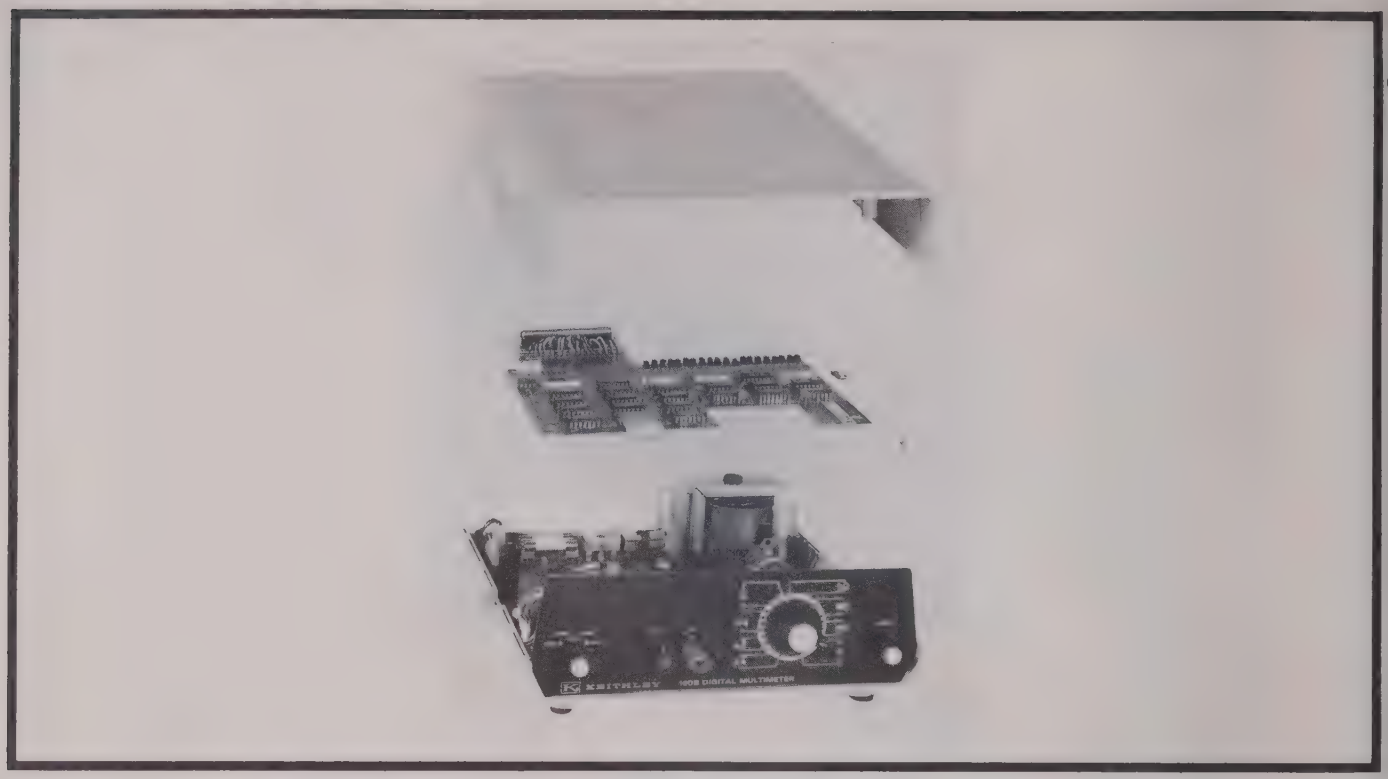


FIGURE 16. Exploded View of Model 160B/1602B.

3-15. HOW TO USE MODEL 1602B DIGITAL OUTPUT.

a. General. The Model 1602B Digital Output provides binary-coded decimal (BCD) outputs and several control inputs. This accessory is available either "factory-installed" or "field-installable". The Model 1602B consists of a single printed circuit board (PC-352) with input and integrally mounted output connector, and an output mating connector with hood.

b. Installation of Model 1602B. The Model 1602B is installed internal to the Model 160B and is powered by the Model 160B line operated power supply.

NOTE

It is not intended that the Model 1602B be used simultaneously with the Model 1688A Battery Pack. To use the Model 1602B, the Model 1688A must be removed and set aside. It is possible, however, for the user to make his own wiring modifications so that the Model 1688A Battery Pack can power the Model 160B while located outside the Model 160B.

To install the Model 1602B, turn the Model 160B over so that the bottom cover faces up. Locate and loosen four slotted screws as shown in Figure 4. The screws are "captive" and should not be completely removed. Once the screws are loosened, hold top and bottom covers together and turn Model 160B so that the top cover is up. Carefully lift off the top cover and disconnect the wires to the Analog Output. Locate 16-pin receptacle J201 on the main circuit board (PC-349). Plug the mating connector (P301) from the Model 1602B into J201, after checking that pin numbers are corresponding. Locate 3-pin plug P208 on the main circuit board (PC-349). Connect J303 from the Model 1602B to P208. Be sure that the "A" of P208 lines up with the "A" of J303. Place Model 1602B board on four spacers with cables positioned as shown in Figure 17. Remove digital-output cover plate from Model 160B top cover. Place top cover back on instrument, after reconnecting Analog Output wires. Turn instrument over and tighten four slotted screws.

c. Pin Identification of Rear Panel Digital Output Connector. The Model 1602B uses a 37-pin connector (J302) to provide all input and output connections to external equipment. Pins are identified as shown in Table 3-7.

CAUTION

DISCONNECT LINE CORD BEFORE OPENING
THE TOP AND BOTTOM COVER.
LINE VOLTAGE ON THE CHASSIS
REPRESENTS A SHOCK HAZARD.

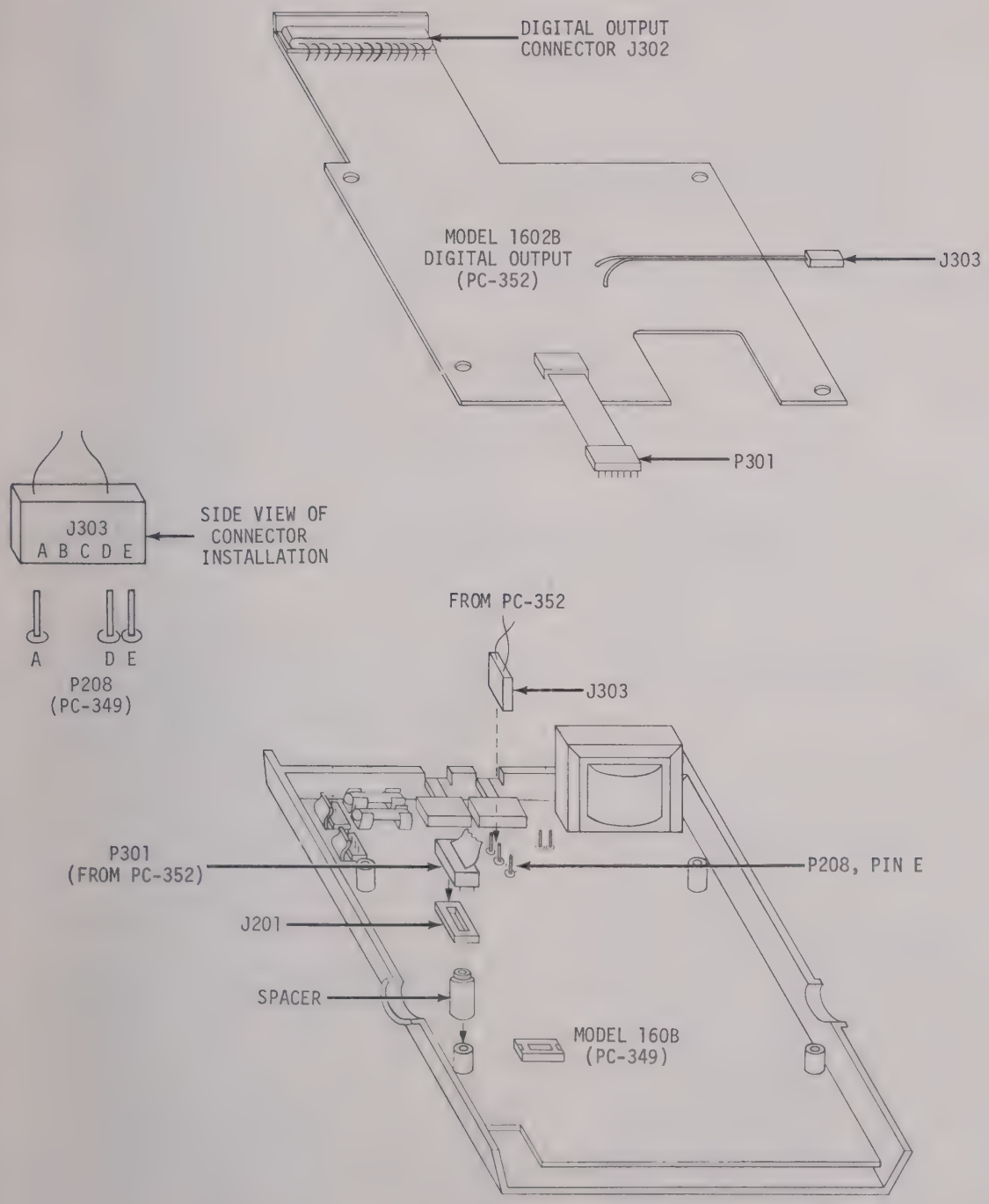


FIGURE 17. Installation of Model 1602B.

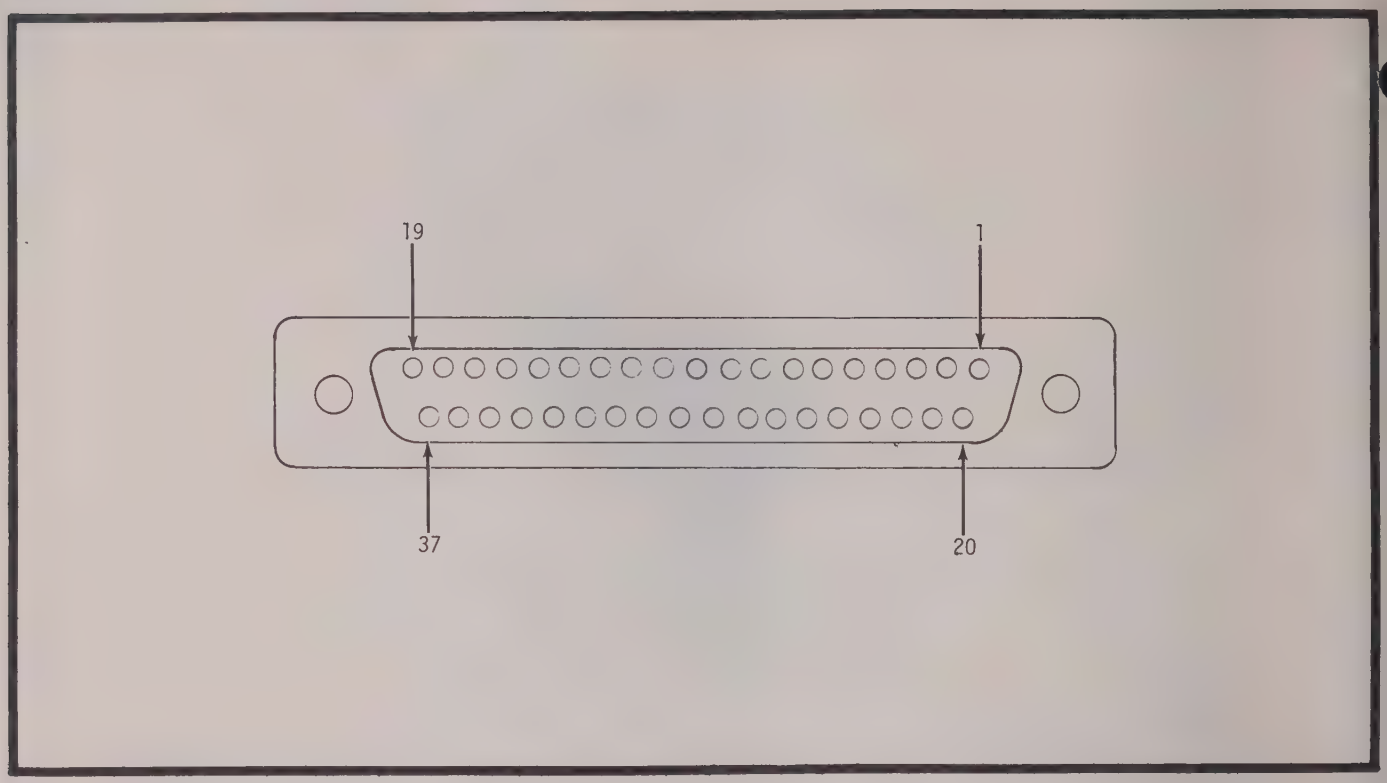


FIGURE 18. Rear Panel Digital Output Connector.

d. Output Data Lines. BCD (1-2-4-8) open-collector positive logic represents each of 3 digits, overrange digit, overload, decimal position, and polarity.

1. Open-collector Output. The output data buffers of the Model 1602B consist of CMOS NOR gates driving individual "open-collector" transistors. A main feature of open-collector outputs is the ability to interface with a variety of data processing equipment types including printers and computers. The open-collector output operates in either a saturated (low-impedance) state or an open (high-impedance) state. It is compatible with many types of logic including TTL, DTL, RTL, and CMOS. The Model 1602B output lines can operate at voltage levels up to +20V, and hence can interface directly with CMOS circuits operating with +15V supplies. In most cases, a pull-up resistor is needed to define the "open" or logic "1" state. The value will depend on the capacitive coupling among wires in the cable and to other circuitry external to the Model 160B/1602B. For operation with 5-volt power supplies, a value of 5k to 10kΩ is usually sufficient, and the minimum value is about 300Ω. The Model 1602B printed circuit board is designed so that pull-up resistors can be mounted on the board itself (rather than added externally). One end of the pull-up resistors can then be connected to an external power supply at pin 18 of the 37-pin output connector (J302). The pc board spacing is designed for 1/4 watt carbon resistors.

a). The open-collector configuration can be used to connect multiple outputs to one input of a data-processing system. For example, if the 1602B is interfaced to a 16-bit computer, the 3 BCD digits may be presented to a 16-bit data register in the computer by setting lines 25, 5, and 24 to logic "0" at a given time. If the DP, overload, polarity, and 1 x 10^3 outputs are wired

TABLE 3-7.
Model 1602B Connector Pin Identification.

Pin No.	Name	Pin No.	Name
1	Not Used	20	Not Used
2	Not Used	21	Not Used
3	DISPLAY HOLD	22	FLAG RESET
4	STROBE, ST-6	23	BCD HOLD
5	STROBE, ST-2	24	STROBE, ST-3
6	STROBE, ST-5	25	STROBE, ST-1
7	LO	26	STROBE, ST-4
8	DP-3 (100.0)	27	DP-2 (10.00)
9	DP-1 (1.000)	28	$\overline{\text{FLAG}}$
10	FLAG	29	POLARITY
11	OVERLOAD	30	DATA, 1 x 10^3
12	DATA, 8 x 10^2	31	DATA, 4 x 10^2
13	DATA, 2 x 10^2	32	DATA, 1 x 10^2
14	DATA, 8 x 10^1	33	DATA, 4 x 10^1
15	DATA, 2 x 10^1	34	DATA, 1 x 10^1
16	DATA, 8 x 10^0	35	DATA, 4 x 10^0
17	DATA, 2 x 10^0	36	DATA, 1 x 10^0
18	EXT VOLTS	37	Not Used
19	Not Used	--	----------

TABLE 3-8.
Model 1602B Output Connector Lines
(Grouped by Function)

Pin No.	Name	Pin No.	Name
25	STROBE 1	26	STROBE 4
36	1 x 10^0	30	1 x 10^3 (OVERRANGE)
17	2 x 10^0	11	OVERLOAD
35	4 x 10^0	29	POLARITY
16	8 x 10^0		
5	STROBE 2	6	STROBE 5
34	1 x 10^1	10	FLAG
15	2 x 10^1	28	$\overline{\text{FLAG}}$
33	4 x 10^1	22	FLAG RESET
14	8 x 10^1		
24	STROBE 3	4	STROBE 6
32	1 x 10^2	9	DP-1 (1.000)
13	2 x 10^2	27	DP-2 (10.00)
31	4 x 10^2	8	DP-3 (100.0)
12	8 x 10^2		
18	EXT. VOLTS	23	BCD HOLD
		3	DISPLAY HOLD
		7	LO

in parallel with some of the BCD-digit outputs, the BCD digits will be unaffected provided lines 26 and 4 are set to logic "1". At another time, lines 25, 5, and 24 may be set to logic "1", and lines 26 and 4 to logic "0". This will present the DP, overload, polarity, and 1 x 10^3 outputs to the same 16-bit register.

b). When a particular 160B/1602B is being operated, line 6 may be set to logic "0", enabling FLAG and $\overline{\text{FLAG}}$. When the data from this particular 160B/1602B is not of interest, line 6 may be set to logic "1", which disables FLAG and $\overline{\text{FLAG}}$. Then, another device may use the same line for interrupt or polling.

c). Since the data is in 4-bit or smaller groups, all output data from the 1602B may be sequentially connected to a 4-bit bus using the same technique described above. This is useful when interfacing to programmable calculators and logic systems where bit-parallel, character-serial data transmission is used.

2. BCD Digits. The 3 least-significant digits of the numerical data are represented in BCD (1-2-4-8) form. Each digit is individually controlled by a strobe line. A "high" output is equivalent to logic "1".

3. Overrange Digit, Overload, and Polarity. These three lines are controlled by the same strobe. The presence of the overrange digit is indicated by a "high" output. An overload condition is indicated by a "low" output. For polarity, "+" is represented by a "high" output.

4. Decimal Point Lines. The three "DP" lines are controlled by a single strobe. The state of these lines is dependent on the setting of the Model 160B Range Switch; the data on these lines is not latched. DP1 is the decimal point to the left of the "hundreds" digit; DP2 is to the left of the "tens" digit; DP3 is to the left of the "ones" digit.

NOTE

During an overload, the numerical data present at the Digital Output is "1777". This could be mistaken for a valid reading unless the "Overload" line is used to signal an overload condition.

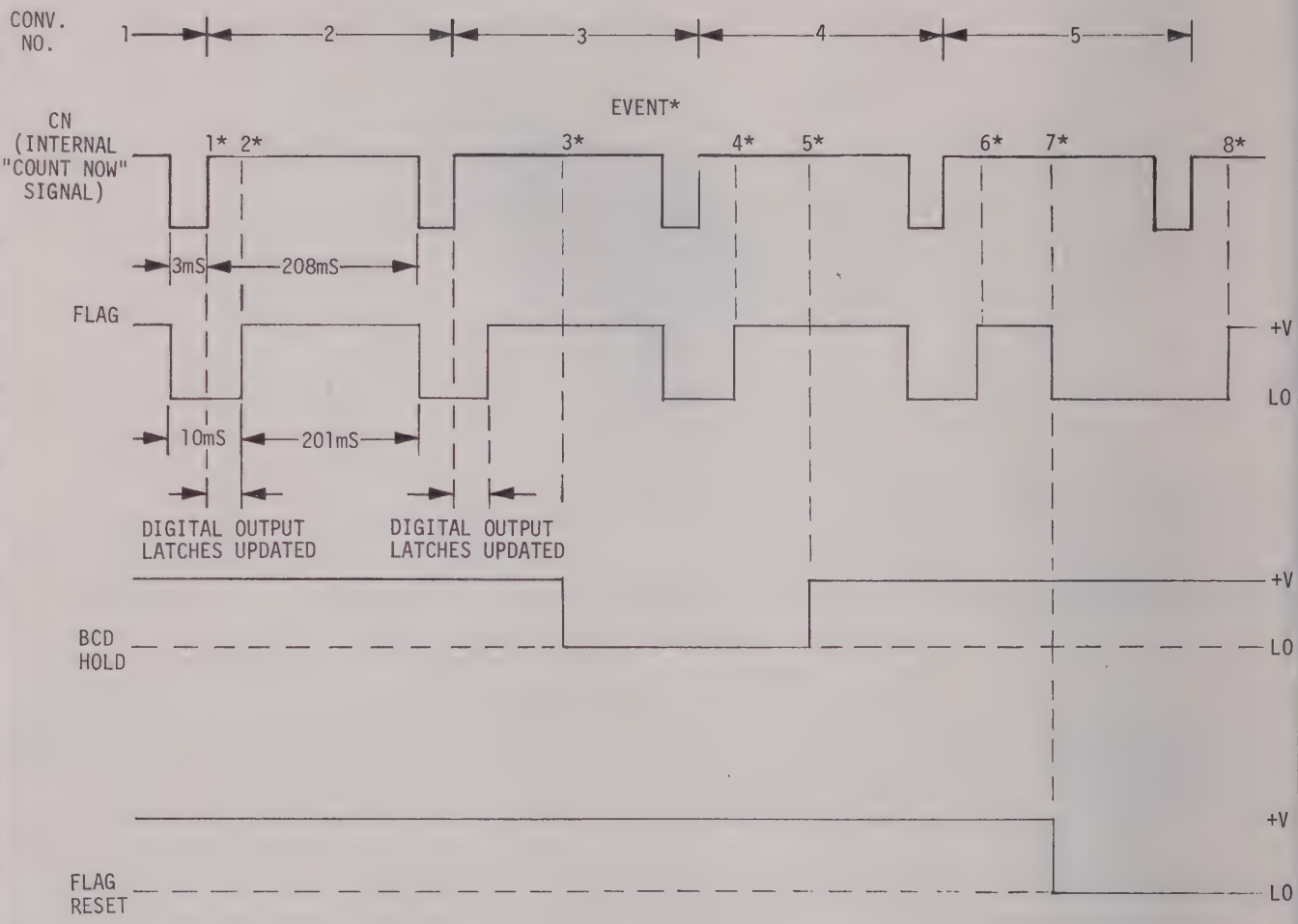
e. Flag and $\overline{\text{Flag}}$. The Flag line is high for approximately 200mS during a "normal" (no Flag Reset) conversion cycle. The Flag line is low for approximately 10mS. (See Timing Diagram for Model 1602B, Figure 19.) During the time that the Flag is high, the data in the Digital Output latches is not changed.

1. Flag Timing. The Flag is synchronized with an internal signal from the Model 160B A-to-D converter. This internal signal, designated "CN" for "COUNT NOW", is high for 2016 clock pulses and low for 32 clock pulses. When "CN" makes the transition from high to low, the Flag also changes from high to low. While "CN" is low, the latches in the Model 160B LSI circuit are updated and the counters in the LSI circuit are reset.

2. Digital Output Latch Updating. "CN" remains low for 3.3mS nominally. At the end of this time, the data from the most recent conversion is present in the output latches of the LSI circuit. This data is presented to both the Model 160B display and the Digital Output is multiplexed form. At the Digital Output, the data must be demultiplexed. This is accomplished by having the 4 multiplex timing signals (from the LSI circuit) enable the Digital Output latches in sequence. Each multiplex signal is high for 825μSec. nominally (8 clock pulses). This means that the Flag line must remain low for at least 4 x 825μSec., or another 3.3mSec, after "CN" goes high. The Flag line is arbitrarily set up to go low for 10mSec. nominally to make sure that the latches in the LSI circuit and the latches in the Digital Output are updated.

NOTE

The "DP" (decimal point) data is not latched at the Digital Output. However, no change in this data will occur during a conversion unless the Range Switch setting is changed.



EXPLANATION OF EVENTS*

1). Conversion cycle #1 complete. Latches in LSI circuit (in Model 160B) updated.
2). Digital Output latches updated with data from conversion #1. "Flag" line goes from "0" to "1".
3). "BCD Hold" goes low (after "Flag" line has gone high).
4). "Flag" line goes high. Digital Output latches still contain data from conversion #2, because "BCD Hold" line is low.
5). "BCD Hold" released (after "Flag" line has gone high).
6). "Flag" line goes high. Digital Output latches now contain data from conversion #4.
7). "Flag Reset" goes from "1" to "0", causing the "Flag" to go from "1" to "0".
8). "Flag" line goes high even though "Flag Reset" line is still low. Digital Output latches contain data from conversion #5.

FIGURE 19. Timing Diagram for Model 1602B.

f. Output Control Lines. The Model 1602B has six Strobe lines, a Flag Reset line, a BCD Hold, and a Display Hold.

1. Strobe Lines. All data outputs are grouped into 3- and 4-line groups. Each group is controlled by a "Strobe" line. Flag and $\overline{\text{Flag}}$ are also controlled by a Strobe line. Logic "1" on a Strobe line turns all the transistor "open-collector" outputs off in a particular group. A logic "0" on a Strobe line enables the data to determine the logic states of the group. The groupings are indicated in Table 3-8. Section d (above) gives additional information on open-collector outputs.

2. Flag Reset Line. Flag may be reset at any time by setting Flag Reset to logic "0". The Flag is reset by the transition of the Flag Reset line from logic "1" to logic "0". The signal at the Flag Reset line may be either a pulse or a level. When a pulse is used, the pulse width should be at least 1μSec. If a level is used, a logic "0" on the Flag Reset line will not prevent the Flag from going high when the next "good data" is available.

3. BCD Hold. If this line is set to logic "0", the data at the Digital Output will not be updated as conversions are completed. Flag will operate normally. When BCD Hold is returned to logic "1", the Digital Output will be updated normally. New data will be available beginning with the next logic "0" to logic "1" transition of the Flag.

The BCD Hold is not synchronized with a particular point in the conversion cycle. When the BCD Hold line is set to logic "0", the "updating" pulses to the Digital Output latches are blocked. If the BCD Hold is activated during the time when Flag is normally low, either none of or some of the Digital Output latches will be updated. If the BCD Hold is released during the time when Flag is normally low, only some of the Digital Output latches may be updated at the next Flag high. For these reasons, the BCD Hold should be activated and released only during the time when the Flag is normally high (this is approximately 200mS regardless of whether Flag Reset is used). The BCD Hold should be activated after Flag has gone from low to high; the BCD hold should be released after the Flag has gone first from high to low and then from low to high.

NOTE

The BCD Hold has no control over the "DP" (decimal point) lines. The logic states of the data on these lines is determined by the setting of the Model 160B Range Switch. The Range Switch setting should not be changed while the Digital Output is in a "Hold mode".

4. Display Hold. This "Hold" line affects the Model 160B LSI circuit directly. When this "Hold" is applied, the numerical data present at the Model 160B display and at the Digital Output is not updated as conversions are completed. The Display Hold line is activated by a logic "0". When Display Hold is returned to logic "1", numerical data at the display and Digital Output will be updated normally.

The Display Hold is not synchronized with a particular point in the conversion cycle. If the Display Hold is activated during the time that the Flag is normally low, numerical data from either the most recent conversion or the conversion previous to it may be retained. A similar situation can occur if the Display Hold is released during the time when Flag is normally low. The Display Hold should be activated after Flag has gone from low to high; the Display Hold should be released after the Flag has gone first from high to low and then from low to high. Unlike the BCD Hold, it is very unlikely that activating or releasing the Display Hold during Flag low time would produce mixed data at the display and Digital Output. If it does not matter whether the retained data is from the most recent conversion or the conversion immediately preceeding it, the Display Hold can be applied arbitrarily. In any operating system however, the Display Hold should be synchronized in some way with the Flag.

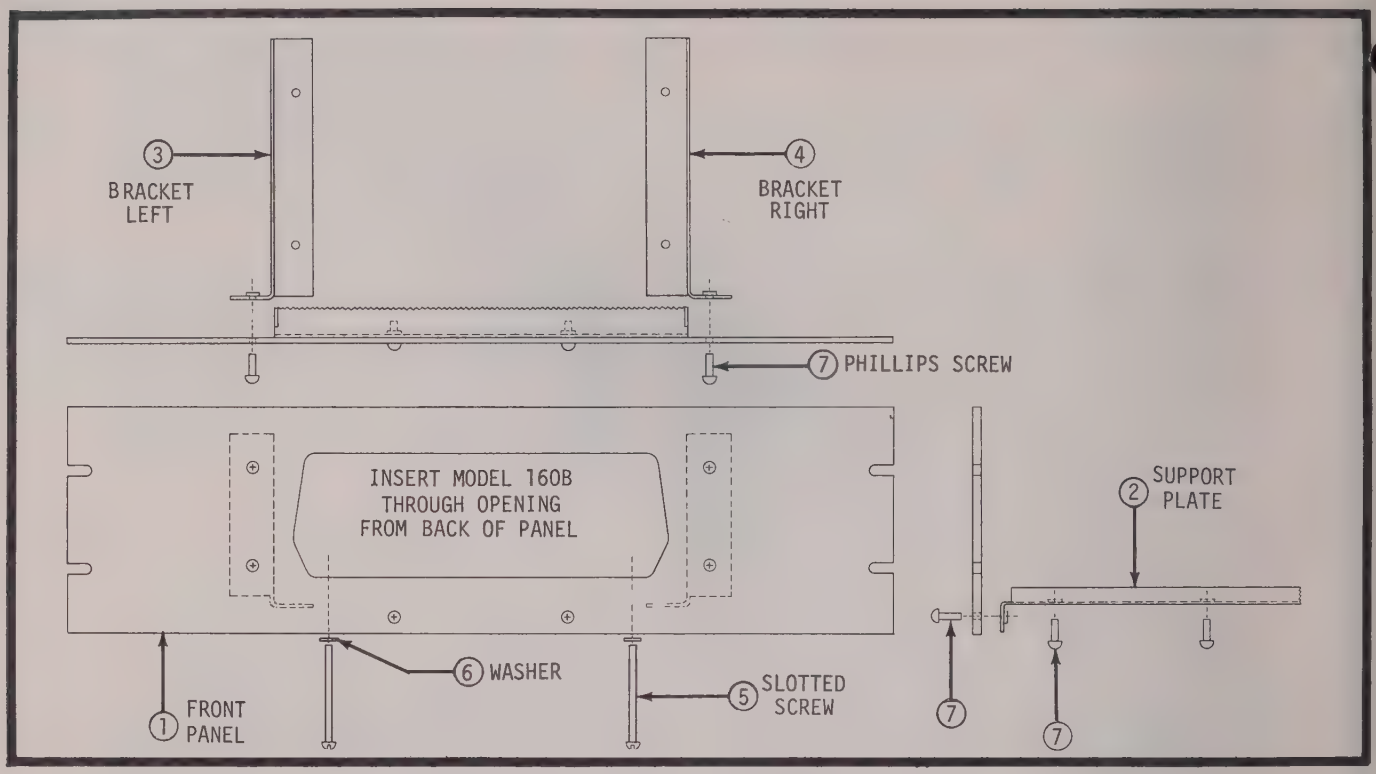


FIGURE 20. Rack Mounting of Model 160B.

3-16. HOW TO RACK MOUNT THE MODEL 160B. The Model 1010 Rack Mounting Kit adapts the Model 160B for standard 5-1/4 in x 19 in. rack mounting, with 11 in. depth behind the front panel.

a. Using two Phillips Screws (Item 7) attach Support Plate (Item 2) to Front Panel (Item 1).

b. Using four Phillips Screws (Item 7), attach left and right side Brackets (Items 3 and 4) to Front Panel (Item 1).

c. Using four Phillips Screws (Item 7) secure left and right side Brackets to Support Plate (Item 2).

d. Assembly of rack hardware is complete except for mounting of Instrument.

e. Rotate "handle" of Instrument so that handle is toward rear of Instrument. (Handle can be removed completely if desired by separating top and bottom covers.)

f. Remove two Slotted Screws (1-1/4 in. long) used to hold top and bottom covers together near front feet.

g. Position Instrument so that holes in bottom of Instrument align with two front holes on Support Plate.

h. Using two Slotted Screws (Item 5) and two Flat Washers (Item 6) secure Instrument to Support Plate. Tighten screws only enough to prevent lateral movement. Do not over-tighten screws since damage to plastic feet could occur.

SECTION 4. THEORY OF OPERATION

4-1. GENERAL. This section contains information to describe the Model 160B circuit operation. The circuits are arranged on a single mother board to facilitate troubleshooting and servicing.

a. The basic digital voltmeter consists of two sections packaged together in one chassis: 1) analog amplifier (with shunt resistors for current measurements and a current source for resistance measurements), 2) analog-to-digital converter.

b. The analog amplifier is a variable-gain chopper amplifier.

c. The analog-to-digital converter is a charge-balancing type converter with five readings/second conversion rate. BCD outputs and external control options are available when used with the Model 1602B Digital Output Kit.

4-2. ANALOG AMPLIFIER CIRCUITRY. The analog amplifier is shown in the simplified block diagram, Figure 21.

a. Voltage Amplifier. The amplifier has a full-range sensitivity variable from 1 millivolt to 100 millivolts. Above 100 millivolts, the input signal is divided down to either the 10mV or 100mV full-range level (See Table 4-1). The signal flow path can be described as follows: An input signal applied at the Input HI terminal is attenuated by a resistor divider. The signal is filtered and applied to a modulator circuit. The ac signal is then amplified and demodulated. A final high-gain dc amplifier provides a dc signal for the Analog Output and A-to-D converter. A resistor divider feeds back a portion of the dc output to provide overall gain accuracy and stability.

1. Output Resistor Divider. This divider is composed of resistors R160A, R160B, R160C, and R160D. These resistors are packaged together as a single network, and the four resistors are matched to within 0.02% of one another (at approx. 23°C). This divider supplies dc feedback to the amplifier input and sets up the three gains of the overall amplifier: X10, X100, and X1000.

2. Input Resistor Divider. This divider is made up of resistors R159A, R159B, and R159C. These resistors are packaged together as a single network, and the three resistors are matched to within 0.02% of one another (at approx. 23°C). (They are matched to within 0.05% with 1200 VDC applied.) This divider attenuates 1V and 100V signals to 10mV, and it attenuates 10V and 1000V signals to 100mV.

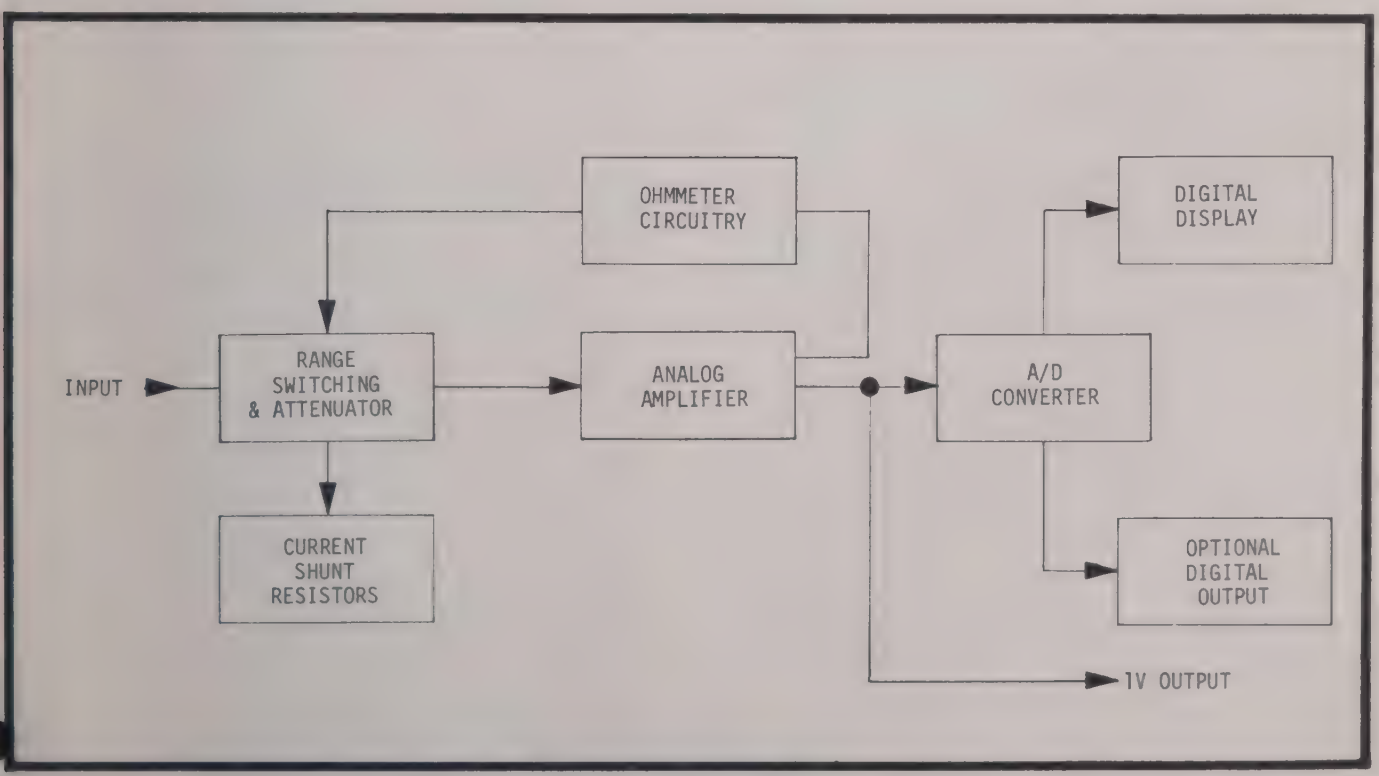


FIGURE 21. Overall Block Diagram.

TABLE 4-1.
Summary of Voltage Sensitivity.

Range	Attenuator Setting	Amplifier Full-Range Sensitivity	Amplifier Gain	Full-Range DC Output
1 mV	--	1 mV	X1000	1 volt
10 mV	--	10 mV	X100	1 volt
100 mV	--	100 mV	X10	1 volt
1 V	1/100	10 mV	X100	1 volt
10 V	1/100	100 mV	X10	1 volt
100 V	1/10,000	10 mV	X100	1 volt
1000 V	1/10,000	100 mV	X10	1 volt

3. Filter Network. Basically, the filter is a 1-section RC low-pass filter made up of R116, R117, and C104. R116 and R117 in series have a nominal resistance value of 112kΩ. At 50 Hz, C104 (.56μF) has a reactance of approx. 6kΩ, and with the 112kΩ produces an attenuation of approx. 20 to 1. This attenuation gives the Model 160B a normal-mode rejection spec of 60 dB above 1 digit on the 100mV range, as an example. "60 dB above 1 digit" means that the Model 160B can reject a 100mV p-p, 50 Hz signal on the 100mV range with no more than a 1 digit error. 100mV p-p at 50 Hz would be reduced to 5mV p-p at the output of the filter. This 5mV p-p, after "chopping" and amplifying is enough to cause amplifier U104 to reach its maximum allowed output level. A signal greater than 5mV at the output of the filter causes U104 to saturate. When saturation occurs, significant DC error signals can be produced at the output of the overall amplifier.

4. Modulator Circuit. This circuit converts an input dc signal to an ac signal with a fundamental frequency component of approx. 220 Hz. The frequency of 220 Hz was chosen because this frequency is not harmonically related to either 50 Hz or 60 Hz. The circuit utilizes a dual MOS-FET (Q102A and Q102B) connected in a series-shunt configuration. This type of series-shunt modulator maintains high input impedance.

5. AC Amplifier. The ac amplifier uses a low-noise integrated circuit, U104. The amplifier feedback network provides a gain of approx. 2000 at the modulating frequency of 220 Hz, while maintaining a gain of 1 for amplifier (U104) dc offset voltages.

6. Demodulator Circuit. The demodulator is synchronized with the input modulator. A JFET, Q103, with low on-resistance is used to alternately attenuate or pass the signal present at the output of ac amplifier U104. The negative portions of the 220 Hz ac signal are allowed to pass which produces a "half-wave-rectified" negative dc signal at the input to dc amplifier, U105.

7. DC Amplifier. This amplifier is composed of resistors R128 and R129, capacitors C113 and C114, and integrated circuit U105. The integrated circuit provides sufficient gain to bring the total open-loop dc gain of the overall amplifier to a minimum of about 20 million. The feedback capacitor, C113 and C114 in series, was selected to give a noise bandwidth of approx. 0.5 Hz to the overall amplifier when it is used at a closed-loop gain of 1000. The integrated circuit, U105, must be capable of driving the feedback network (R160A, B, C, and D), the A-to-D converter, and the Analog Output to ±2 VDC.

8. Modulator-Demodulator Drive Circuit. CMOS inverters, U103A and U103B, provide opposite phase square waves used to drive MOS-FET modulator transistors Q102A and Q102B. Inverter U103B also provides a drive signal for demodulator JFET Q103. Resistors R121, R122, and R123, and capacitors C108 and C109 affect the rise and fall times of the square-wave drive signals. R121 adjusts the rise and fall time of Q102A only, so that the total charge, both positive and negative, transferred to the input can be minimized. Any net charge at the input creates a current, which in the Model 160B is specified to be less than ±10pA. The frequency of the drive signal is determined by the clock circuit and LSI U201. Circuitry in LSI U201 divides down a nominal clock frequency of 9680 Hz to produce 220 Hz.

9. Offset Current Zero Circuit. See Section 4-2a8.

10. Front Panel Zero. The voltages across potentiometer R114 are set-up by a stable zener reference diode, VR101, and an IC op-amp, U102. These voltages are approximately ±2 VDC, which give R114 an adjustment range of approximately 450μVolts. A typical Model 160B has an internal offset of about -100μVolts in the chopper amplifier. Hence, adjusting the Front Panel Zero from end to end will typically produce about +125μVolts and -325μVolts. This "extra" adjustment at the negative end of the range allows sizeable positive offsets to be compensated for, as is the case when the Zero is used for test lead compensation on the low-ohms Ranges. 200mΩ of test lead resistance will produce +200μVolts of zero offset, which can be "bucked out" by the Zero control. (See also Section 3-5d). Zeroing of the chopper amplifier output is actually accomplished by having the "Zero" circuit either source or sink whatever current is present in feedback resistor R160D. For example, an offset voltage of -111μV on the feedback line produces a current of -1μA in resistor R160D (111.135Ω). A voltage of -1μVolt at the wiper of Zero potentiometer R114 will produce an equal current of -1μA in resistor R115 (1MΩ). With this zeroing scheme, for the chopper amplifier output to be at zero, the voltage at the feedback line will always be offset from the voltage at the input by a constant, say for example, -111μVolts. (The feedback line connects to the junction of R160C and R160D).

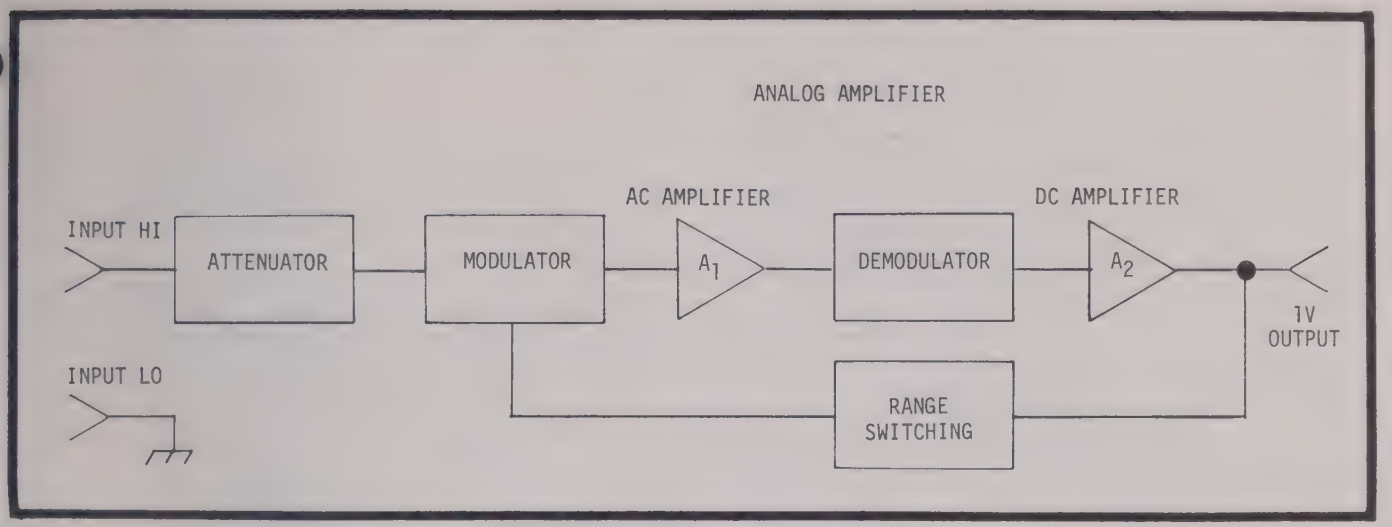


FIGURE 22. DC Voltage Operation.

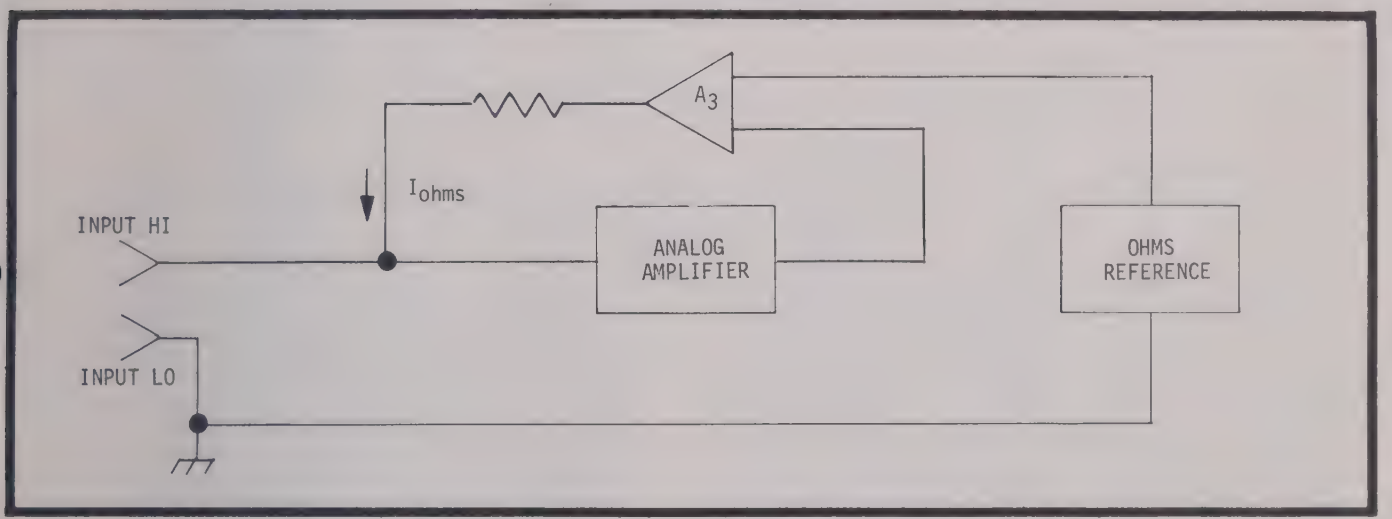


FIGURE 23. Resistance Operation.

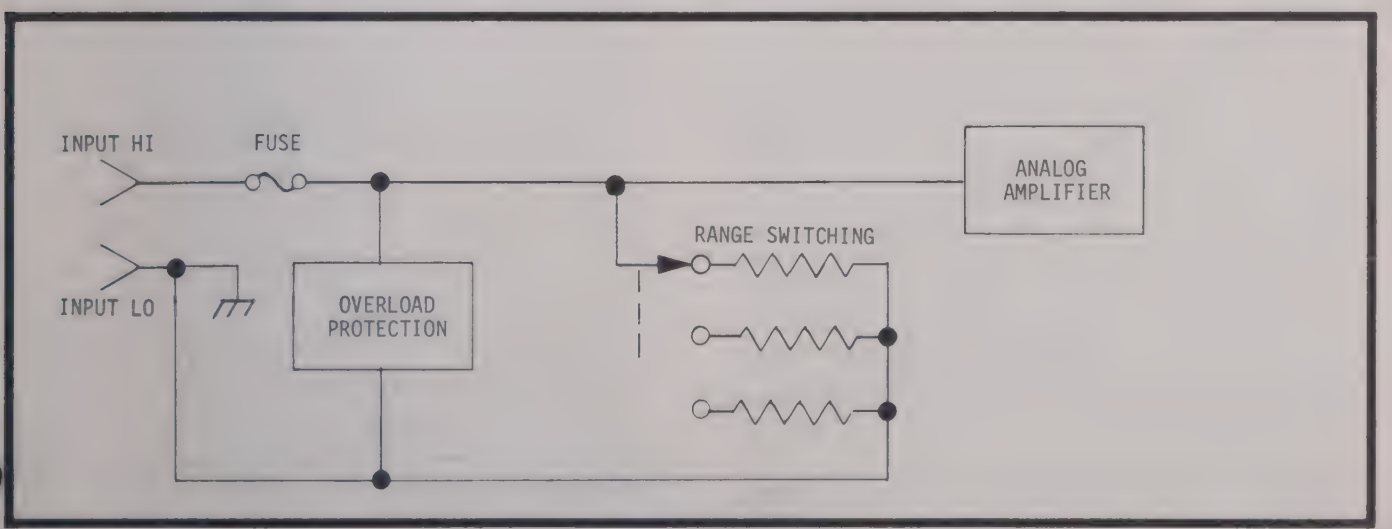


FIGURE 24. Current Operation.

b. Ammeter Circuitry. Currents are measured with the Model 160B by shunting resistors across the input of the analog-amplifier. The resistors used for the current ranges are R139 through R146 (and R163). Table 4-2 shows the value of the shunt resistor and the analog amplifier full-range sensitivity for each current range of the Model 160B. On the "high-current" ranges (100μA through 1000mA), where the value of the shunt resistor is low, the analog amplifier senses the voltage drop right at the resistor. On the "low-current" ranges (10nA through 10μA), the analog amplifier senses the voltage drop at the Model 160B HI terminal. To approximately determine the total input resistance of the Model 160B on the highest current ranges, add 0.1Ω internal wiring resistance to the value listed for the shunt resistor (Table 4-2). Diode network CR108 and fuse F101 provide over-current protection on the 1μA through 1000mA ranges. The diode network will not allow the input voltage to exceed approximately 1.5 volts for currents up to 3A, thus protecting the shunt resistors. For currents above 3A, the fuse will open. On the 10nA and 100nA ranges, the shunt resistors by themselves can withstand 250-volt overloads.

TABLE 4-2.
Summary of Current Sensitivity

Range	Shunt Resistance	Amplifier Gain	Amplifier Sensitivity
10 nA	1 MΩ	X100	10 mV
100 nA	100 KΩ	X100	10 mV
1 μA	10 KΩ	X100	10 mV
10 μA	1 KΩ	X100	10 mV
100 μA	100 Ω	X100	10 mV
1 mA	10 Ω	X100	10 mV
10 mA	1 Ω	X100	10 mV
100 mA	0.1 Ω	X100	10 mV
1000 mA	0.1 Ω	X10	100 mV

c. Ohmmeter Circuitry. This circuitry provides a number of fixed currents by using a stable voltage reference, a differential voltage amplifier, and a series resistor. The circuit is also protected against voltage overloads of 250 volts at the Model 160B input terminals.

1. Voltage Reference. An adjustable divider made up of resistors R105, R106, and R107 provides an output of approximately -100mV from a stable zener reference, VR101. This divider is connected to the inverting input of the differential voltage amplifier. (The divider is actually adjusted so that the amplifier output is an accurate +100mV when the input terminals of the Model 160B are shorted.)

2. Differential Voltage Amplifier. This amplifier circuit includes U101, resistors R102, R104, R108, R109, R110, and protection circuitry. The resistors and IC op-amp are connected as a unity gain differential amplifier; resistor R110 adjusts the gain accuracy. The inverting input of the circuit is connected to a reference voltage. The non-inverting input is connected to the feedback voltage of the analog amplifier. Because the feedback voltage is equal to the input voltage of the analog amplifier to a high degree of accuracy, the following relations hold:

$$V_{out\ (amp.)} = -V_{ref} + V_{fb}$$
$$-V_{ref} + V_{in}$$
$$-(-100mV) + V_{in}$$
$$+100\ mV + V_{in}$$

Hence, the output voltage of the differential amplifier is equal to the input voltage, whatever that may be, plus a positive voltage of 100mV. This +100mV and a series resistor set up a fixed reference current.

3. Current Setting Resistors. Table 4-3 lists the Model 160B Resistance Ranges, the series resistors, the currents which are set up, and the analog amplifier sensitivity at full-range.

TABLE 4-3.
Summary of Resistance Ranges

Range	Series Resistor	Current	Amplifier Sensitivity
1 Ω	100 Ω	1 mA	1 mV
10 Ω	100 Ω	1 mA	10 mV
100 Ω	100 Ω	1 mA	100 mV
1 kΩ	1 kΩ	100 μA	100 mV
10 kΩ	10 kΩ	10 μA	100 mV
100 kΩ	100 kΩ	1 μA	100 mV
1 MΩ	1 MΩ	100 nA	100 mV
10 MΩ	10 MΩ	10 nA	100 mV
100 MΩ	100 MΩ	1 nA	100 mV
1000 MΩ	1000 MΩ	100 pA	100 mV

4. Overload Protection. When a positive overload voltage up to +250 VDC is applied to the Model 160B input terminals, CR101 is reverse biased and prevents damage to IC amplifier, U101. Current flow from the +250 VDC source is through a current setting resistor and R102. R102 has a value of 499kΩ which prevents excessive currents in the low-value current-setting resistors. When a negative overload voltage up to -250 VDC is applied to the input terminals, Q101 is biased to limit the current to approximately 2mA. Maximum current possible from Q101 and R102 at -250 VDC is approximately 2.5mA, which is low enough to protect the low-value current setting resistors. Q106 has a normal diode drop for positive overloads, and an approximate -6V zener drop for negative overloads. It protects the input of U101.

4-3. ANALOG-TO-DIGITAL CONVERTER. The analog-to-digital converter includes the following circuits: an "absolute-value" circuit, a polarity detector, an integrator and threshold detector, an LSI circuit, a clock, an LED display, and display drive circuitry.

a. Absolute-value Circuit. This circuit produces a positive DC output voltage regardless of the polarity of the input voltage. The relationship is defined by:

$$V_{out} = k\ |V_{in}|$$
where k = +1

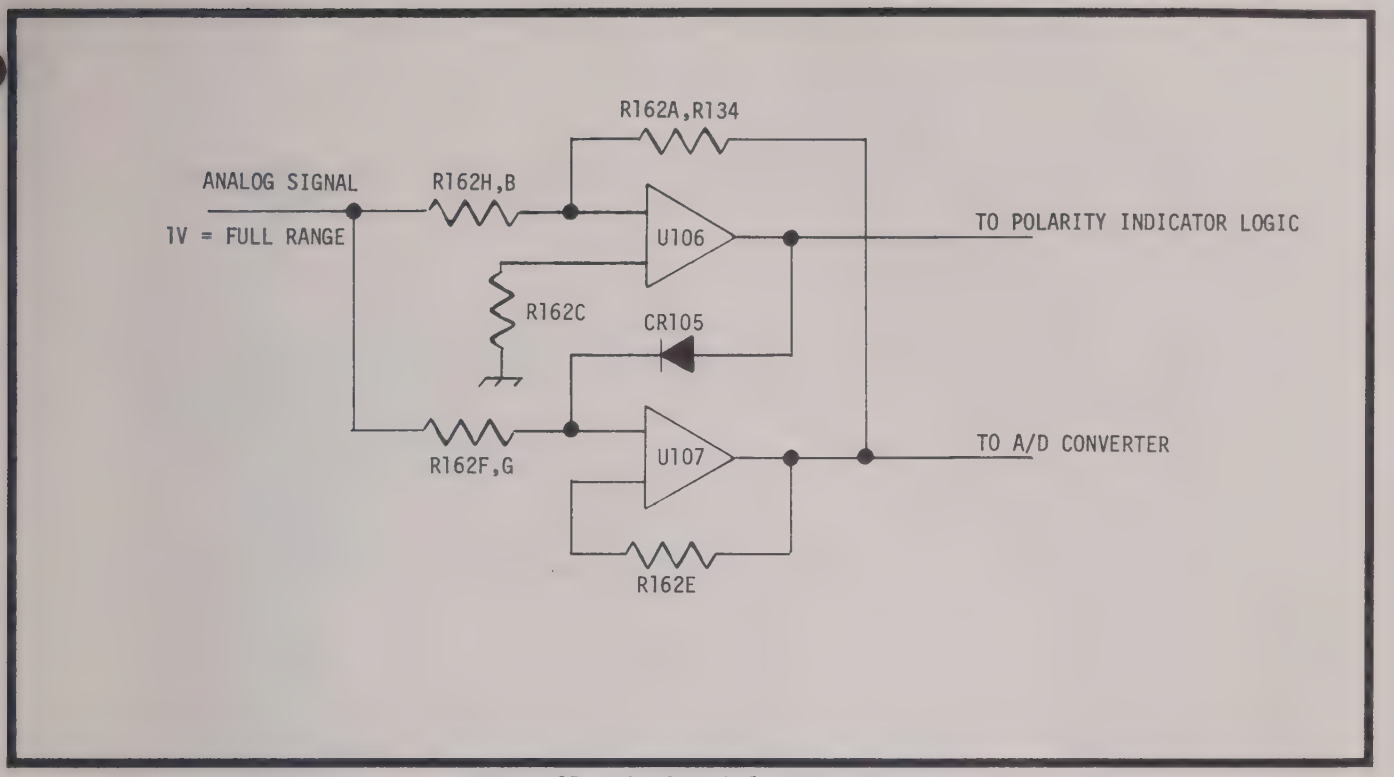


FIGURE 25. Absolute Value Detector.

Actual operation is as follows: A positive dc voltage at pin 12 of R162 produces an equal dc voltage at the output of U107, and also causes the output of U106 to go negative. When this happens, CR105 is reverse biased, and U107 is effectively isolated from the action of U106. A negative dc voltage at pin 12 of R162 causes the output of U106 to go positive; the output of U106 must go sufficiently positive to forward bias CR105 and drive the input of U107. In this situation, U107 and U106 together function as a two-stage inverting amplifier. The gain of this inverting amplifier is accurately set to -1 by internal adjustment R134 ("-DC CAL") and resistors R162A, B, and H. R135 ("RECT ZERO") sets the zero offset voltage of U106 equal to -1/2 the zero offset voltage of U107. (Thus, the zero offset is the same for both positive and negative dc signals, and this zero offset can be compensated for with the "DISPLAY ZERO", R136.) Capacitors C115, C116, C117, and C118 provide filtering of AC components present in the input signal.

b. Polarity Detector. The polarity detection circuit uses two transistors, U108C and U108D, of an IC transistor array. These transistors are used as a simple differential-voltage amplifier with one output connected to power supply common. A positive-going output of U106 causes the collector of transistor U108D to go negative. When this happens, Q206 is shut off, and the "+" segments of display DS201 are also shut off. A negative-going output of U206 causes the base of transistor U108D to be clamped at approximately -0.7V, which shuts off the collector current of U108D. As a result, the voltage at the collector of U108D goes to a level of approximately +0.7V, which is sufficient to drive Q206 into saturation and turn on the "+" segments of DS201.

c. Integrator, Threshold Detector, and LSI Circuit. These circuits make up the heart of the analog-to-digital conversion process. The actual conversion technique is based on a charge-balancing principle. A block diagram of the basic converter action is shown in Figure 27. A positive voltage at R161A causes the output of amplifier U109 to go negative; the rate of change of this output is a function of the input voltage, resistors R161A, B, and capacitor C120. The negative-going output of U109 causes the threshold detector (amplifier U110) output to change to a positive level. A positive level represents a "1" at the J input of the J-K flip-flop (the K input is a "0" due to the inverter). The charge and discharge periods for the integrator are determined by the state of the Q output of the J-K flip-flop. When the Q output is high, diode U108A is reverse biased, and the integrator can only be charged by a voltage from the Absolute-value Circuit. When the Q output is low, diode U108A is forward biased, and discharge of the integrator occurs. Because Q and $\overline{Q}$ states can be changed only when a clock pulse is present, the charge and discharge periods are also a function of the clock frequency. The overall a-to-d converter operates in a free-running manner, but the timing period for a conversion is set at 2016 counts. The reading at the display is derived by counting the number of clock pulses in all the discharge periods during a span of 2016 clock pulses. This selective counting is easily accomplished by an AND gate, as shown in Figure 27. The reference current is adjusted so that a voltage of +1V at the integrator input (R161A) produces a total discharge period containing 1000 clock pulses. For R161A and R161B each having a value of 1kΩ, the reference current must be adjusted to a value of approximately 1mA to produce the proper conversion ac-

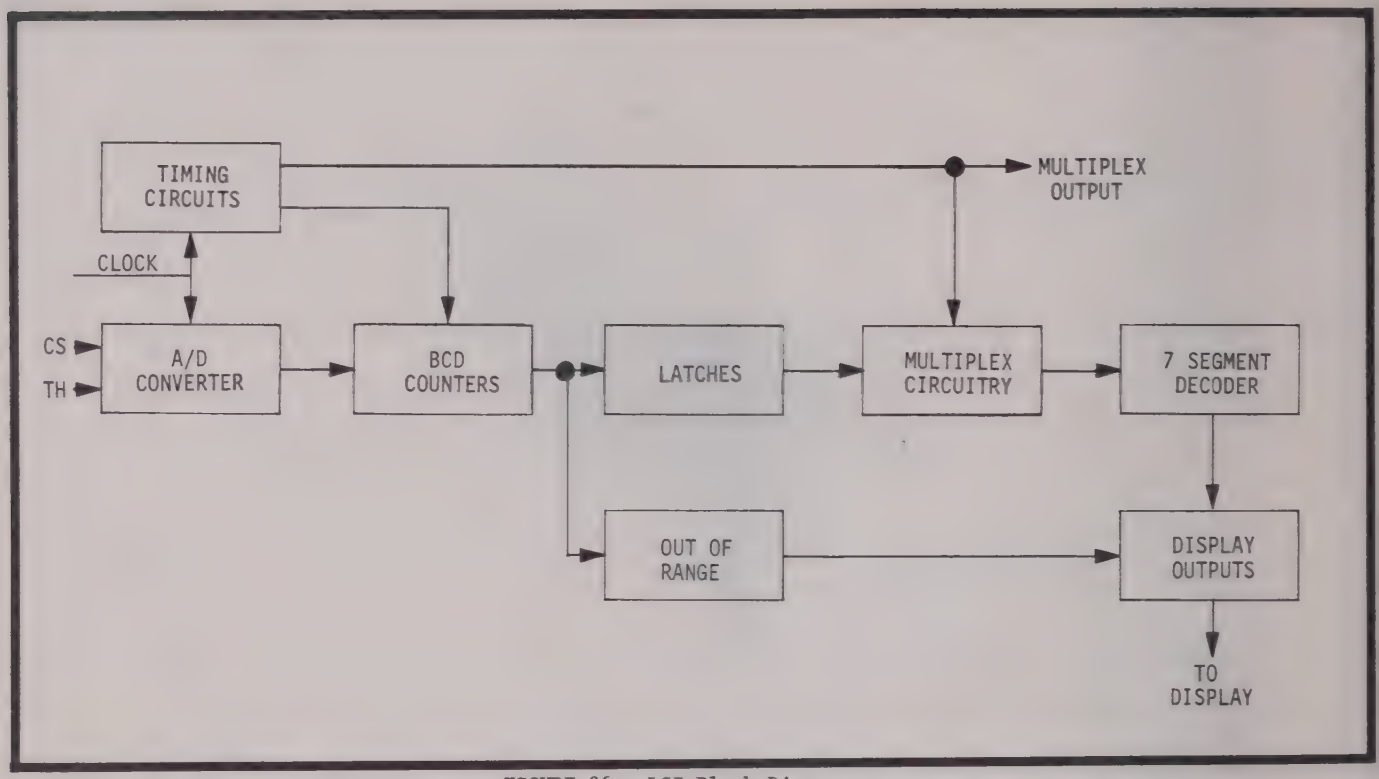


FIGURE 26. LSI Block Diagram.

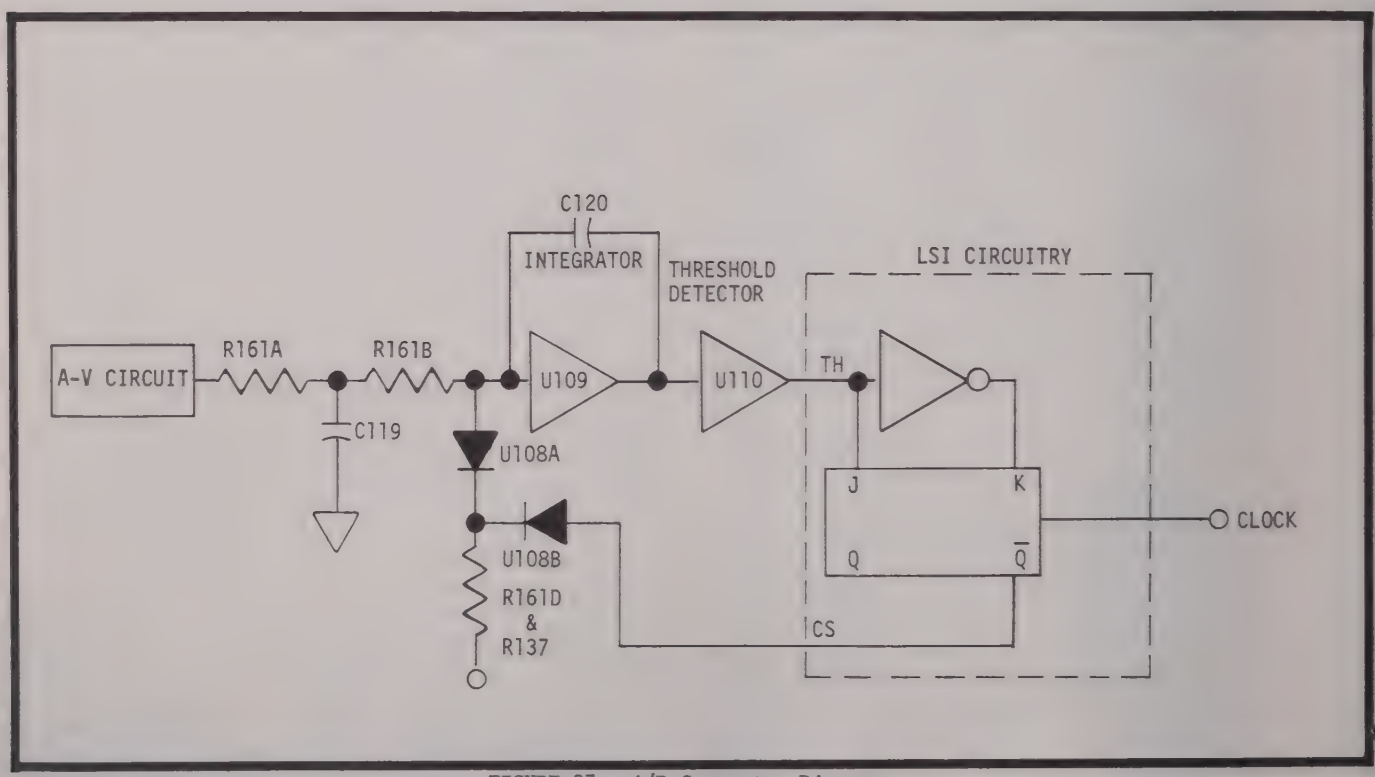
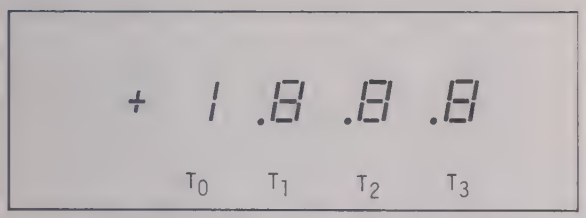
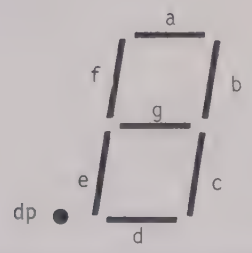


FIGURE 27. A/D Converter Diagram.



IDENTIFICATION OF MULTIPLEX LINES



IDENTIFICATION OF SEGMENTS

FIGURE 28. Identification of Segments and Multiplex Lines.

curacy. Once the reference current is set, an input of 250mV is represented as 250 counts out of 2016, and 1.999V is represented as 1999 counts out of 2016. An input of 2V or greater causes the 3 least-significant digits to blank.

NOTE

One complete conversion cycle is 2048 counts. The BDC counter is able to count to 2016 before it is stopped. During the remaining 32 counts, the information in the BDC counter is transferred into latches, and then the BCD counter is reset to zero. 2048 counts at a clock frequency of 9680 Hz results in a total conversion time of approximately 0.21 seconds (which is equivalent to about 5 readings/sec.).

d. Clock. The clock circuit makes use of an IC timer, U202, hooked up for astable operation. Resistors R205 and R206, together with capacitor C201, set up a non-symmetrical square-wave with a nominal frequency of 9680 Hz and a duty cycle of about 5%. Q201, along with R202, R203, and R204 is used to invert the output of U202.

e. Display. The Model 160B digital readout is made up of three LED seven segment displays (DS202, DS203, and DS204) and one LED "±1" display (DS201).

1. Display Multiplexing. The LED displays are multiplexed to minimize the number of interconnections, simplify the drive circuitry, and reduce power consumption. The timing for the multiplexing is determined by the LSI circuit, U201, and is set up such that each multiplex line is high for 8 clock pulses (approximately 825μSec.) and low for 24 clock pulses. The four multiplex lines are designated as T0, T1, T2, and T3, and each line controls an LED display (See Figure 28). Circuit operation during a particular multiplexing interval, say T0, is as follows: When T0 is high, the output of U203A is low. This produces a current in R218B of approximately 10mA which is sufficient to drive Q202 into saturation, and effectively connect DS201 to the +5V power line. Simultaneously, the LSI circuit supplies the correct digital information for DS201 to the display segment drivers. The same circuit action then occurs during the other multiplexing intervals --- T1, T2, and T3.

2. Display Drive. The display drivers are designed to handle a variety of LED common-anode displays. Because "constant-current" drivers are used, displays with different voltage drops per segment can be driven without changing the circuit power consumption. The drivers take the same current from the +5V power supply regardless of whether the display segment drop is 1V or 3.5V. Actual operation of a particular segment, segment A for example, is as follows: When the "A" line of LSI circuit U201 is high, then the open-collector output of buffer U204A is shut off. As a result, the voltage at pin 5 of resistor network R217 is approximately +1.3V, which is also the voltage at pin 9 of transistor array U205. Assuming a base-to-emitter voltage of 0.7V, then the voltage at pin 10 of U205 is approximately +0.6V; this voltage generates a 15mA current in the 40Ω emitter resistor.

When the "A" line of U201 is low, then the output of U204A is also low, and the transistor current source (pins 9, 10, and 11 of U205) controlled by U204A is shut off. Transistor Q207, and its associated circuitry duplicates the operation of the other six transistor current sources. The "decimal point" lines of DS202, DS203, and DS204 are controlled by the Range Switch, and the currents for the decimal points are determined by R209, R210, and R211.

4-4. POWER SUPPLY. The Model 160B uses either line power or battery power (when the Model 1668A is installed).

a. Line Power. Transformer T201 has two tapped primary windings which are connected in series or in parallel depending on the position of line switches S201 and S202. Fuse F201 is in series with winding 4-5-6 for all settings. Fuse F202 is connected only when winding 1-2-3 is connected in parallel with winding 4-5-6. The secondary of T201 has two tapped windings. The lower taps (11 and 10; 8 and 7) are used in line mode. The upper taps (12 and 10; 9 and 7) are used in charge mode.

1. +5V Supply. In LINE operation, the ac voltage between transformer leads 10 and 11 is full-wave rectified by CR203. The filtered full-wave dc voltage (approximately 10V) is regulated by integrated circuit U207. The output regulated voltage is 5V ±5%.

2. -12V Supply. In LINE operation, the voltage between transformer leads 7 and 8 is full-wave rectified by CR204. The filtered full-wave dc voltage (approximately 18V) is regulated by integrated circuit U208. The regulated output voltage is -12V ±5%.

b. Battery Power. When BATTERY mode is selected, the Model 1668A Battery Pack is connected into the inputs of U207 and U208 while the line voltage is disconnected at the secondary. The 8.4V batteries provide input power for the +5V supply. The 16.8V batteries provide input power for the -12V supply. Battery test point A provides a measurement of the 16.8V battery supply with respect to power supply low. Therefore, the voltage measured is the difference between the battery supply and the -12 volt output which is approximately +4.8 volts. Battery test point B provides a measurement of the 8.4V battery supply.

c. Battery Charging. In the Charge mode, the 8.4V batteries are connected between the output of CR203 and the input of U207. To accommodate the batteries in series with the regulator (U207), one AC input of CR203 is switched to a higher voltage tap (pin 12) on transformer T201. The 16.8V batteries are connected between CR204 and U208, and CR204 is switched to pin 9 of T201. Actual charging of the 8.4V batteries is accomplished by the current pulses in filter capacitor C203; charging of the 16.8V batteries is by current pulses in C206.

TABLE 4-4.
Pin Identification for LSI

Pin No.	Desig.	Function	Voltage Levels	Pin No.	Desig.	Function	Voltage Levels
1	f	Segment drive	+5V = ON, OV = OFF	15	dp	Decimal point	+5V = ON, OV = OFF
2	g	Segment drive	+5V = ON, OV = OFF	16	÷44		
3	T1	Multiplex line	+5V = ON, OV = OFF	17	T0	Multiplex line	+5V = ON, OV = OFF
4	T3	Multiplex Line	+5V = ON, OV = OFF	18	F1	Not Used	----
5	HOLD			19	F4	Not Used	----
6	MR	Not Used	---- ----	20	+5V	Power, +5V	+5V
7	TH	Threshold input	+5V or -12V	21	-12V	Power, -12V	-12V
8	CLK	Clock	Approx. 10kHz, +5V to -12V	22	COM	Common or "LO"	OV
9	b	Segment drive	+5V = ON, OV = OFF	23	CN		
10	a	Segment drive	+5V = ON, OV = OFF	24	T2	Multiplex line	+5V = ON, OV = OFF
11	d	Segment drive	+5V = ON, OV = OFF	25	R4	Not Used	----
12	e	Segment drive	+5V = ON, OV = OFF	26	R1	Not Used	----
13	c	Segment drive	+5V = ON, OV = OFF	27	R2	Not Used	----
14	CS	Current Switch	+5V = integrate mode	28	F2	Not Used	----

4-5. MODEL 1602B DIGITAL OUTPUT. The Digital Output includes a seven segment-to-BCD converter, latches for demultiplexing, output data buffers, a timer to set up the Flag, Flag Reset circuitry, and other supporting circuitry. It is made up primarily of CMOS logic circuits.

a. Seven Segment-to-BCD Converter. This converter uses one Hex Inverter (U301), three Quad 2-Input NOR gates (U302, U303, and U304), and one Dual 4-Input NOR gate (U305). The converter logic takes the multiplexed seven-segment data directly from the LSI circuit in the Model 160B. The output of the converter is a multiplexed BCD code. This code is supplied to the inputs of "D-type" latches for demultiplexing. When all inputs to the seven-segment converter are low, as occurs when the Model 160B is in an overload condition, the converter output is a BCD "7".

b. Latches. To demultiplex the BCD data for the "ones", "tens", and "hundreds" digits, three Quad Clocked "D" latches are used (U310, U311, and U312). U310 is enabled during multiplex interval "T3", U311 during "T2", and U312 during "T1". The Overload and Polarity lines are latched by Dual 'D'-Type Flip-Flop, U308; this flip-flop is enabled during "T1". The 1 x 10^3 (Overrange) line is latched by one section of Dual 'D'-Type Flip-Flop U309, and is enabled during the "T0" interval. All the "T"-line signals are inverted by a Quad 2-Input NAND gate, U307-A, B, C, and D. Then the inverted signals are shaped into pulses by R-C networks (10kΩ and 470pF). In the Quad Latches, data is transferred from input to output while the enabling pulse is low; latching occurs on the positive-going edge of the pulse. In the "D" Flip-Flops, data is transferred from input to output only during the positive-going transition of the enabling pulse.

c. Output Data Buffers. The data buffers consist basically of five Quad 2-Input NOR gates (U314 through U318) driving twenty open-collector NPN transistors (Q301 through Q320). The 10kΩ resistors in series with the transistor bases are located in thick film resistor networks. The output transistors have a very high current gain (400 minimum at 10mA collector current); this allows them to be driven into saturation even at the low base currents that the CMOS NOR gates can supply. (The output data lines are specified to be at a voltage level less than +0.5 volt while sinking +15 milliamperes.)

d. "Strobe" Circuit. One Hex Buffer, U313, is used to control five groups of data lines, and also to control Flag/Flag. A particular "strobe" circuit includes a diode, a 10kΩ "pull-up" resistor, and a CMOS Buffer gate. The diode is used to allow voltages up to +15 volts to control the "strobe" circuit. The output of a particular Buffer gate drives one input of each 2-Input NOR gate in a particular output data group. A logic "1" at the input of a "strobe" circuit produces a logic "1" at one input of a NOR gate; this produces a logic "0" at the output of the NOR gate, regardless of the logic state of the data at the other input of the NOR gate. A logic "0" from the NOR gate shuts off the output transistors.

e. Timer Circuit (for Flag/Flag). The timing circuit for the Flag uses a monolithic bipolar integrated circuit, U306. This "timer" is hooked up to operate in a monostable mode. It is triggered by the negative-going edge of the "CN" (or "COUNT NOW") waveform. (The "CN" signal is generated in the LSI circuit of the Model 160B, and its negative-going edge indicates that the counting cycle for a particular A-to-D conversion is complete.) Once the "timer" is triggered, its output remains at logic "1" for a period of time determined by R301 (100kΩ) and C301 (0.1 μF) - in this case, 10mS. The 10mS high time allows the latches in the Model 160B LSI circuit to be updated and the latches in the Digital Output to be updated. The "timer" output goes to other circuitry which is controlled by the Flag Reset Line.

f. Flag Reset Circuit. The Flag Reset circuit uses three gates out of a Quad 2-Input NAND gate, U319, and one "D" Flip-Flop out of a Dual 'D'-Type Flip-Flop, U309. This circuit allows Flag (Flag) to be reset at any time when Flag (Flag) is at logic "1" (logic "0"). Operation is as follows: When Timer U306 is triggered by "CN" (See Section e above) its output goes to logic "1". A logic "1" at the S1 input of U309 sets Q1 of U309 to logic "1". Q1 controls the output of NAND gate U319B. When Q1 is at logic "1", U319B re-inverts the inverted output of Timer U306, so that the Flag signal is present at pin 4 of U319B. When Q1 is at logic "0", the output of U319B (pin 4) is high regardless of what the Timer is doing. Q1 is set to logic "0" by a signal on the Flag Reset line. A high-to-low transition on the Flag Reset line produces a low-to-high transition at the C1 (clock) input of U309. When this occurs, a logic "0" is transferred from the D1 (data) input of U309 to the Q1 output. (If "Flag" is high at this time, it immediately goes low). Q1 is reset to a logic "1" when the output of the Timer goes high again.

g. BCD Hold. This Hold circuit is activated by a logic "0" at pin 23 of the 37-pin Digital Output connector, J302. The Hold remains in effect as long as the logic "0" is present. A logic "0" at pin 23 puts a logic "0" at one input of each gate in the Quad 2-Input NAND gate, U307. With a logic "0" at one input, each NAND gate output is high regardless of the signal at the other input. By this action, the "T-line" signals are prevented from enabling the Digital Output latches. Once the BCD Hold is activated (after the Flag line has gone high), the data from the most recent conversion can be retained in the Digital Output latches indefinitely (until the BCD Hold is released). See also, Section 3-15f3, "BCD Hold".

h. Display Hold. Display Hold is activated by a logic "0" at pin 3 of the 37-pin Digital Output connector, J302. NAND gate, U320-D, inverts the sense of the control signal. This inverted signal then goes to the LSI circuit in the Model 160B, where it prevents the LSI circuit latches from being updated. The numerical data at the Model 160B display and at the Digital Output will remain unchanged as long as the correct control signal level (logic "0") is present. See also, Section 3-15f4, "Display Hold".

SECTION 5. ACCESSORIES

MODEL 1601 AC-DC PROBE

GENERAL. The Model 1601 is a combination ac-dc probe that enables the user to measure voltages from 45 Hz to 45kHz when used with the Model 160B. The slide switch (S101) can be used to select either AC mode or straight-through DC Mode.

SPECIFICATIONS:

DC Mode: Straight-through probe does not alter any Model 160B specifications except: 1) 150 picofarads input capacitance 2) 0.5 ampere maximum current 3) 0.3 ohms resistive offset 4) ±20 microvolts thermal offset.

AC MODE (Voltage only):
- RANGE: 250 volts rms maximum.
- TRANSFER ACCURACY: ±3% of reading, ±0.1 volt, 45 Hz to 45kHz into a 10MΩ ±10% load. Peak responding, calibrated in rms of a sine wave.
- INPUT IMPEDANCE: 0.5 megohm, shunted by less than 20 picofarads.
- MAXIMUM OVERLOAD: Peak ac plus dc must not exceed 400 volts.

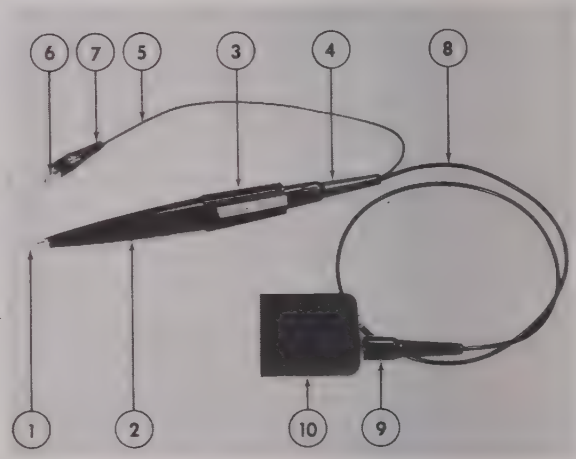
CONNECTOR: Shielded Banana Plug.

DIMENSIONS, WEIGHT: 6 in. long x 3/4 in. diameter (150 x 20 mm), 3 ft. (1 m) cable, net weight 1/4 pound (0,1 kg).

MAINTENANCE:
Since the probe assembly should provide good service with normal handling no maintenance is usually necessary. The probe body (Items 2 and 3) is fastened together at the factory using a special solvent. Therefore the probe should not be disassembled. If repair is necessary, contact the Keithley Representative in your area.

MECHANICAL PARTS LIST:

Item No.	Description	Keithley Part No.
1	Tip	24654B
2	Body, Front	24656C
3	Body, Rear	24655C
4	Strain Relief	18676B
5	Cable, Ground (13" long)	SC-33
6	Clip, Alligator (Ground)	AC-10
7	Insulator (Black)	AC-11
8	Cable (40" long)	SC-30
9	Strain Relief	18676B
10	Can Shield	25128A



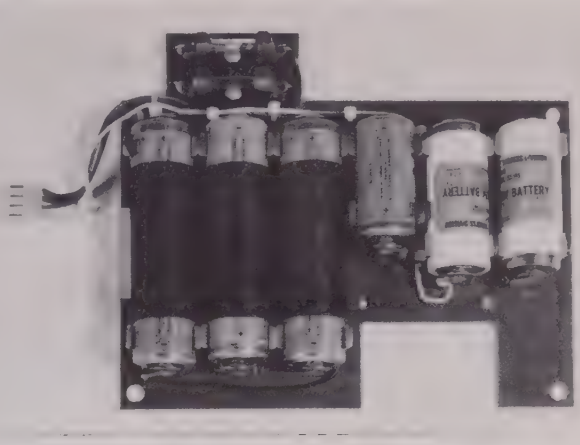
ELECTRICAL PARTS LIST: (See schematic 24669C)

Circuit Desig.	Description	Mfr. Code	Mfr. Part No.	Keithley Part No.
J101	Banana Plug (2 req'd)	JOHN	108-750-2	BG-3
S101	Switch, AC-DC	KI	Special	SW-334
C101	Capacitor, 0.047μF	STAND	M2W-F-0.047μF	C197-.047M
C102	Capacitor, 0.1 μF	POT	MW1A-0.1μF	C86-.1M
D101	Transistor, NPN, Case TO-106	FAIR	2N3565	TG-39
D102	Transistor, NPN, Case TO-106	FAIR	2N3565	TG-39
D103	Diode	MOT	1N4006	RF-38
R101	Resistor, 3.92 MΩ, 1%, 1/4W, CbF	DALE	DC-1/4-3.92M	R178-3.92M
R102	Resistor, Selected in Test*	IRC	CEA-TO-*	R88-*
R103	Resistor, 1 MΩ, 0.1%, 1/8W, MtF	DALE	MFF-1/8-1M	R179-1M
R104	Resistor, 100 Ω, 10%, 1/4W, Comp	OHM	CB-101-10%	R76-100

Model 1688A Rechargeable Battery Pack

Description: The Model 1688A is a field-installable rechargeable battery pack for use with the Model 160B. The Model 1688A includes seven nickel-cadmium "C" cells and one 16.8V nickel-cadmium pack.

Specifications:
- Operate Time: Continuous operation of Model 160B from full charge is 6 hours minimum.
- Recharge Time: 1-1/2 hours per hour of discharge (fully charged within 12 hours).
- Added Weight: 2 pounds (1 kg).
- Added Power When Charging: 4 watts.
- Fused for 1 ampere.
- Storage Temperature: -25°C to +45°C

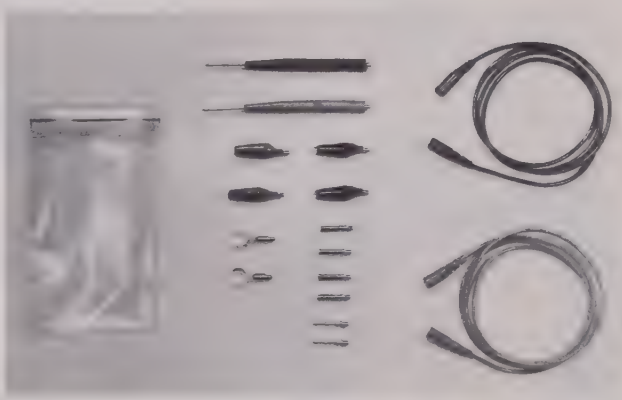


Model 1683 Universal Test Lead Kit

Description: The Model 1683 is a set of flexible test leads, 40 in. (1 m) in length, with interchangeable screw-on adapters.

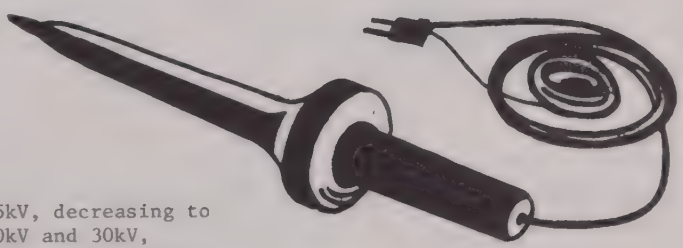
Contents:

Qty.	Description
2	Test Leads, 40 in. (1m) 1 red, 1 black
4	Alligator clip adapter
4	Banana plug adapter
2	Probe. 1 red, 1 black
2	Spade lug adapter
2	Phone tip adapter



Model 1600 High Voltage Probe

The Model 1600 High Voltage Probe may be used with a voltmeter having a nominal input resistance of 10 megohms in the dc volts function. The division ratio is 1000 to 1. The maximum voltage which can be measured is 40 kilovolts.



VOLTAGE RANGE: 0 to 40,000 volts dc.*
INPUT RESISTANCE: 1000 megohms.
DIVISION RATIO: 1000:1.
RATIO ACCURACY (WITH 10MΩ LOAD): ±1.5% at 25kV, decreasing to ±2.0% at 20kV and 30kV, ±3.0% at 10kV and 40kV, and ±4.0% at 1kV.
RATIO STABILITY: 0.01% per °C, ±0.1% per year.
HEATING EFFECTS: Self-heating due to application of high voltage for periods in excess of 1 minute will cause a maximum of 0.2% additional error at 40kV (error is less at lower voltages).
ENVIRONMENT: 0°C to 50°C, 0% to 80% relative humidity up to 35°C. Storage: -25°C to 70°C.
DIMENSIONS, WEIGHT: 3 in. maximum diameter x 15-1/4 in. long (76 x 387 mm), 4-1/2 ft. (1,4 m) cable and ground clip lead to banana plug. Net Weight: 12 oz. (341 g).

*Ac response at 1kV is flat within ±10% from 20 Hz to 120 Hz. Division ratio is dependent on input impedance of multimeter used.

Model 1682 RF Probe

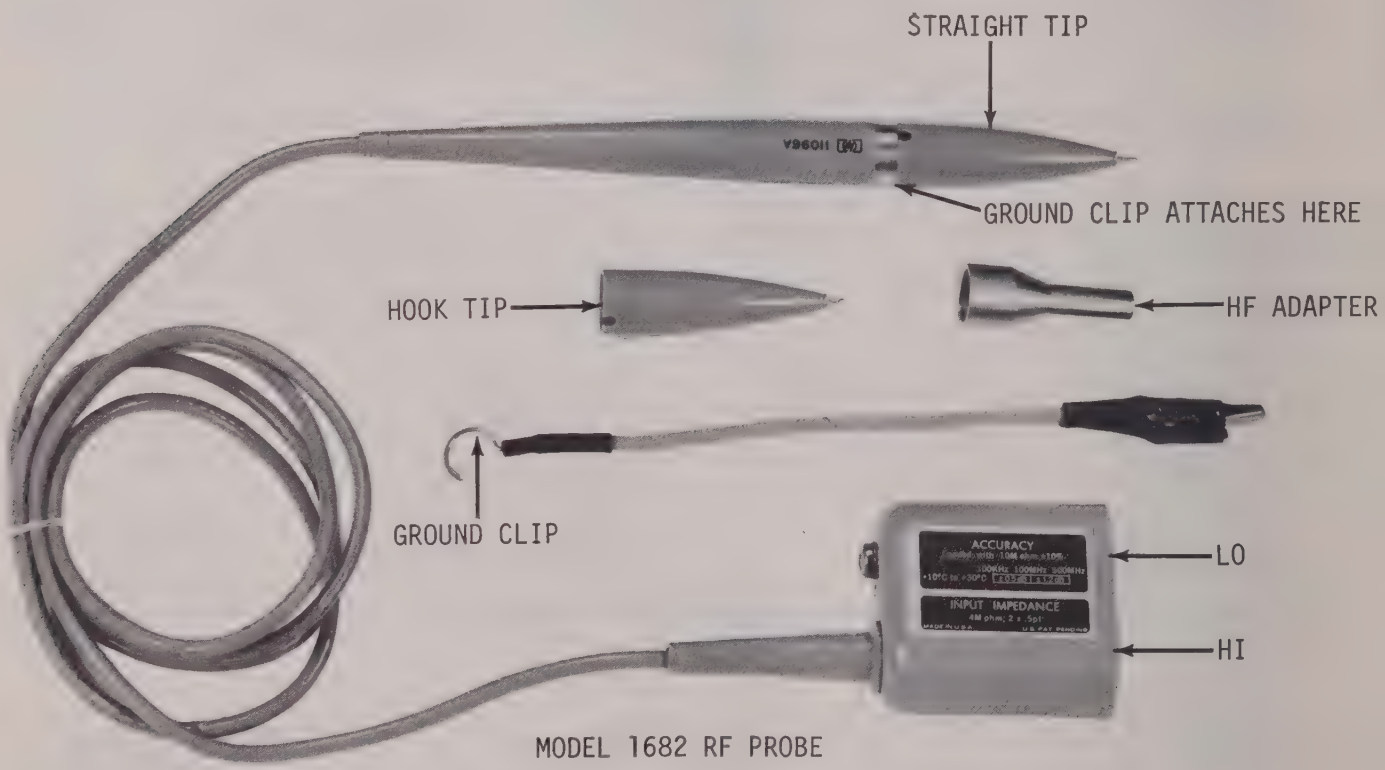
Description: The Model 1682 is an accessory probe which adapts the Model 160B for measurements to 100MHz.

Specifications:

Transfer Accuracy: ±5%, 100kHz to 100MHz (20°C - 30°C), useable 1kHz to 1GHz peak responding, calibrated in rms of a sine wave.
Input Impedance: 4 megohms shunted by 2 picofarads.
Max. Allowable Input: 30V rms ac, 200V dc.

Contents:

Qty.	Description
1	RF PROBE
1	STRAIGHT TIP
1	HOOK TIP
1	GROUND CLIP
1	HF ADAPTER
1	BANANA PLUG ADAPTER (Not used with Model 160B)
1	10MΩ RESISTOR



MODEL 1682 RF PROBE

Model 1609 Calibration Cover

Description: The Model 1609 is an accessory calibration cover for use with the Model 160B. The cover has appropriate openings for access to calibration adjustments on the printed circuit board.

Model 1681 Clip-On Test Lead Set

Description: The Model 1681 is a set of test leads, 48 in. (1,2 m) in length, terminated by a banana plug and spring-action clip-on probe.

SECTION 6. MAINTENANCE

6-1. GENERAL. This section contains information necessary to maintain the instrument. Included are procedures for electrical Performance Checks, Calibration, Troubleshooting, and Battery Replacement and Charging.

6-2. REQUIRED TEST EQUIPMENT. Recommended test equipment for checking and maintaining the instrument is given in Table 6-1. Test equipment other than recommended may be substituted if specifications equal or exceed the stated characteristics.

6-3. PERFORMANCE VERIFICATION. Use the following procedures to verify basic operation of the instrument. All measurements should be made at ambient temperature of approximately 25°C and relative humidity below 50%. If the instrument is out of specification at any point, perform a complete calibration as given in Section 6-4. For each function that is checked, an additional uncertainty due to temperature coefficient should be considered if the ambient temperature is different from 25°C.

NOTE

This procedure is intended to verify only the basic accuracy of the Model 160B in voltage, current, and resistance modes. Test equipment accuracy is specified at X10 better than measurement accuracy.

a. Battery Check. (With Model 1688A Battery Pack installed).

1. Check for proper installation of individual cells in the battery pack making note of polarity of cells as shown in Figure 6.

2. Set Power Switch to "BAT".

3. Connect Voltmeter (A) between test point "B" and LO to verify the "C"-cell 8.4 volt supply. Connect Voltmeter (A) to test point "A" to verify the "Button"-cell 16.8 volt supply. Voltage readings at each test point should be in accordance with Table 6-2.

IMPORTANT

The instrument must be operated in the BAT mode in order to obtain a valid battery condition at test points A and B. This will ensure that the batteries are supplying power to the instrument. If the voltages are measured when the Model 160B is operated in the LINE mode, a different reading may be observed since the batteries are not connected and therefore do not supply power to the instrument.

TABLE 6-1.
Recommended Test Equipment for Performance Verification

Item	Description	Minimum Specification	Manufacturer	Model
A	Voltmeter, Digital	10.00V @ 0.2%	Keithley	168
B	Voltage Source	1,10,100,1000V dc @ 0.005%	Fluke	343A
C	Voltage Divider	100:1 @ 0.01% 1000:1 @ 0.025%	ESI	622A/10K
D	Current Source	1mA, 10mA, 100mA, 1A @ 0.02%	Fluke	382A
E	Resistance Source	1Ω @ 0.1% 10Ω @ 0.04% 100Ω, 1KΩ, 10KΩ 100KΩ, 1MΩ, 10MΩ @ 0.02%	General Radio	1433-H
F	Ohmmeter	100Ω @ 0.4% 10MΩ @ 0.3%	Keithley	168
G	Resistance Source*	10^8Ω @ 0.25%	Welwyn	M14-10^8-0.25%
H	Resistance Source*	10^9Ω @ 1% *(resistor in shielded enclosure)	Welwyn	M51-10^9-1%

TABLE 6-2.
Summary of Battery Voltage Levels at Test Points

Test Point	Range	Normal	Recharge If Below	Batteries Tested
A	2.5V to 9V	4.8V	2.5V	BA-29
B	7V to 10.5V	8.4V	7V	BA-30

b. Input Resistance Check.

1. Select 1000V range.

2. Measure input resistance using Ohmmeter (F).

3. Resistance should be 10 megohms ± 1%.

c. Voltage Accuracy Check.*

1. Select 1mV range.

2. Apply a short (low-thermal copper) to the input terminals.

3. Adjust front panel Zero Control (R114) as necessary to achieve a ±.000 display.

4. Remove short.

5. Apply a dc voltage to input of Model 160B as given in Table 6-3, and select appropriate range.

6. For each voltage range, verify that the Model 160B reading is within the tolerance stated.

d. Resistance Accuracy Check.

1. Select the 1Ω range.

2. Connect Resistance Source (E) to input and adjust Model 160B zero for a ±.000Ω reading.

3. Verify that the Model 160B reading is within the tolerance stated in Table 6-4 for 1Ω, 10Ω, and 100Ω ranges.

4. With Resistance Source (E) connected and set to 0Ω, select the 1mV range and adjust the Model 160B zero for a ±.000mV reading.

5. Verify that the Model 160B reading is within tolerance stated in Table 6-4 for 1kΩ, 10kΩ, 100kΩ, 1MΩ, and 10MΩ ranges.

6. Connect Resistance Source (G).

7. Verify 100MΩ range.

8. Connect Resistance Source (H).

9. Verify 1000MΩ range.

TABLE 6-4.
Accuracy Check for Resistance

Source Input	Source Accuracy	Display Reading	Tolerance on Reading**
1 Ω	±0.1%	1.000 Ω	±5 digits
10 Ω	±0.04%	10.00 Ω	±4 digits
100 Ω	±0.02%	100.0 Ω	±4 digits
1kΩ	±0.02%	1.000kΩ	±4 digits
10kΩ	±0.02%	10.00kΩ	±4 digits
100kΩ	±0.02%	100.0kΩ	±4 digits
1MΩ	±0.02%	1.000MΩ	±4 digits
10MΩ	±0.02%	10.00MΩ	±4 digits
100MΩ	±0.5%	100.0MΩ	±101 digits
1000MΩ	±2%	1000 MΩ	±301 digits

**See Specifications for temperature coefficient for resistance.

e. Current Accuracy Check.

1. Fuse Check.

a). Select 1000mA range.

b). Measure resistance between input terminals, using ohmmeter (F).

c). Verify that resistance is less than 1 ohm.

d). An open circuit condition indicates that the current protection fuse is either not installed or is "blown". Replace fuse F101 on pc board (PC-349) as necessary.

TABLE 6-3.
Accuracy Check for DC Voltage

Source (B) Input	Divider (C) Setting	Range	Over-all Accuracy	Display Reading	Tolerance on Reading**
1.000000 V	0.001	1 mV	±0.03%	1.000 mV	±2 digits
1.000000 V	0.01	10 mV	±0.015%	10.00 mV	±2 digits
10.00000 V	0.01	100 mV	±0.015%	100.0 mV	±2 digits
1.000000 V	--	1 V	±0.005%	1.000 V	±2 digits
10.00000 V	--	10 V	±0.005%	10.00 V	±2 digits
100.0000 V	--	100 V	±0.005%	100.0 V	±2 digits
1000.0000 V	--	1000 V	±0.005%	1000 V	±2 digits

TABLE 6-5.
Accuracy Check for Current

Source (B) Setting	Source (E) Setting	Range Range	Source Accuracy	Display Reading	Tolerance! on Reading**
0.11 V	10 MΩ	10 nA	±0.07%	10.00 nA	±5 digits
1.01 V	10 MΩ	100 nA	±0.025%	100.0 nA	±3 digits
1.01 V	1 MΩ	1 µA	±0.025%	1.000 µA	±3 digits
1.01 V	100 KΩ	10 µA	±0.025%	10.00 µA	±3 digits
1.01 V	10 KΩ	100 µA	±0.025%	100.0 µA	±3 digits
Source (D) Setting					
1 mA		1 mA	±0.02%	1.000 mA	±3 digits
10 mA		10 mA	±0.02%	10.00 mA	±3 digits
100 mA		100 mA	±0.02%	100.0 mA	±4 digits
1000 mA		1000 mA	±0.02%	1000 mA	±4 digits

**See Specifications for temperature coefficient for dc current.

2. Accuracy Verification.

a). Connect Resistance Source (E) in series with Voltage Source (B) to form a current source (for 10nA, 100nA, 1µA, 10µA, and 100µA ranges).

b). Set Voltage Source (B) to 0.000000V and Resistance Source (E) to 0Ω.

c). Connect "Current Source" to Model 160B input.

d). Select 1mV range on the Model 160B.

e). Adjust zero on the Model 160B for a ±.000mV display.

f). Select 10nA range on the Model 160B.

g). Verify the 10nA, 100nA, 1µA, 10µA, and 100µA ranges using the source settings given in Table 6-5.

NOTE

Voltage Source (B) must be set 10mV high to compensate for the Model 160B "input drop" at full-range.

h). Connect Current Source (D) in place of previous current source.

i). Verify that the 1mA, 10mA, 100mA, and 1000 mA ranges are within the tolerances given in Table 6-5.

6-4. ADJUSTMENT/CALIBRATION PROCEDURE. The following adjustments should be performed when any specification has been determined to be out of tolerance. For checking the Model 160B to its maximum published specifications, the Performance Verification procedures given in Section 6-3 should be used. For maintaining the Model 160B on a six-month recalibration cycle, Tables 6-8, 6-9, and 6-10 should be used. The "Tolerance on Reading" given in Tables 6-8, 6-9, and 6-10 is adjusted to allow for time drift of critical components, and also the effects of humidity. Tables 6-8, 6-9, and 6-10 also give the probable component to be investigated if a range does not meet specifications after the Adjustment Procedure has been completed.

IMPORTANT

The Model 160B factory-calibration is at a level that will assure all specifications are met for a period of 12 months after shipment from the factory. For subsequent recalibration, a six-month re-cal cycle is recommended since component tolerance drift may prevent recalibration to stringent factory-calibration levels without component replacement. The following calibration procedure uses levels that will assure that the instrument meets published specifications for a six month period without requiring component changes. Adjustments should be performed under laboratory conditions of approximately 25°C and less than 50% relative humidity.

a. How to Open Instrument. Turn the Model 160B over so that the bottom cover is facing up. Loosen the four slotted screws on the bottom panel (the screw heads should come up to about the top of the holes). Turn the instrument top side up. Carefully lift off the top cover, and disconnect the wires to the Analog Output.

CAUTION

Care should be taken to avoid contact with line voltages at various points on the pc board when the line voltage cord is connected.

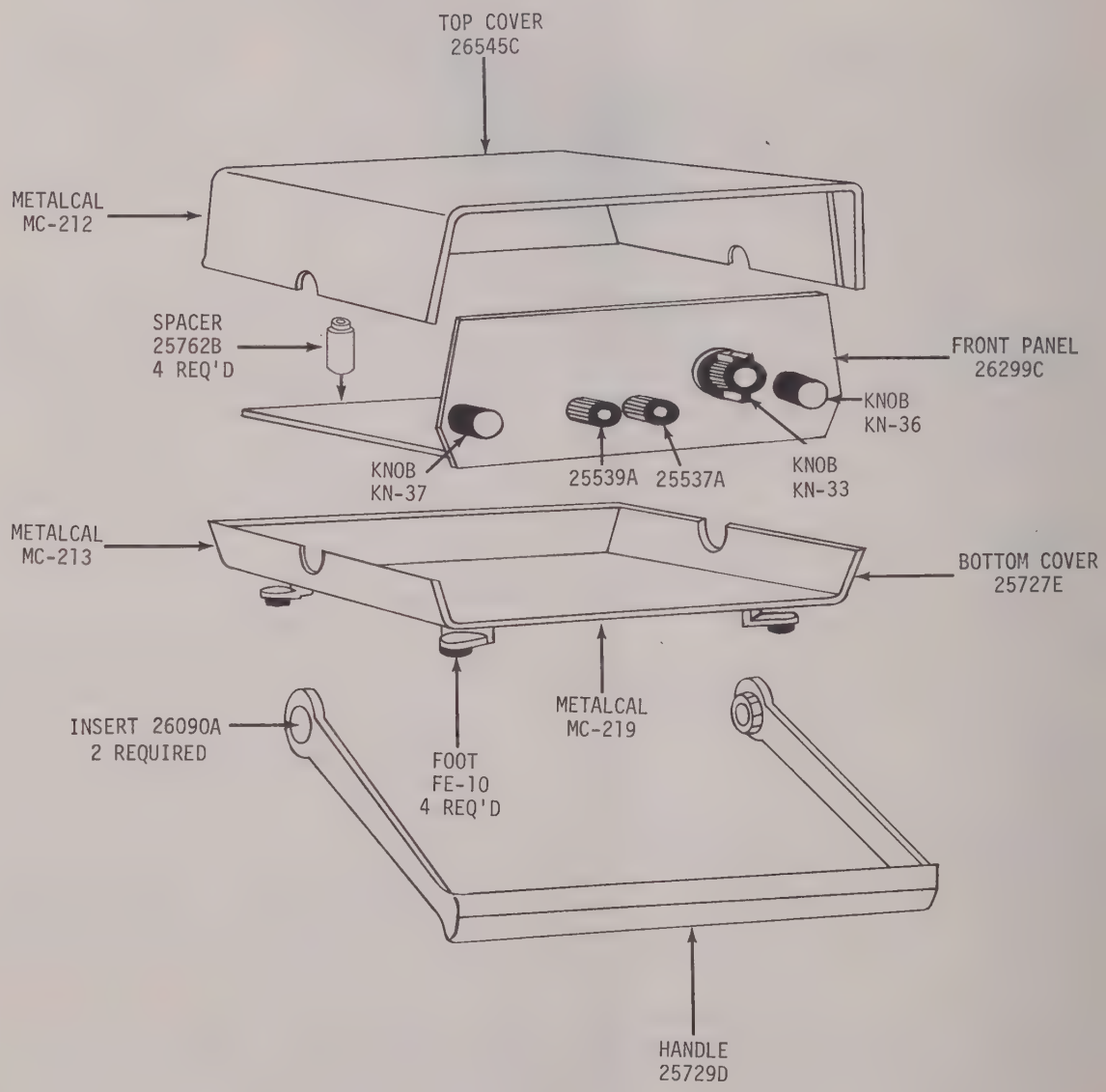


FIGURE 29. Top and Bottom Cover Assembly.

TABLE 6-6.
Recommended Test Equipment for Calibration

Item	Description	Minimum Specification	Manufacturer	Model
I	Voltmeter, Digital	100mV @ 0.015% 1V @ 0.01%	Data Precision	2540A1
J	Voltage Source	1V @ 0.005%	Fluke	343A
K	Voltage Divider	10:1 @ 0.005% 1000:1 @ 0.025%	ESI	622A/10K

b. Power Supply Check. The power supply voltages can be checked with Voltmeter (I) from Table 6-6.

1. +5V Regulated Supply. Check the Line Voltage Switches (at rear of instrument) to see if they are set correctly. Measure the voltage at TP202 with respect to Input Lo. The voltage should be +5V, ±5% in the "LINE" mode of operation, and also in the "CHG" and "BAT" modes of operation if batteries are installed.

2. -12V Regulated Supply. Check the Line Voltage Switches (at rear of instrument) to see if they are set correctly. Measure the voltage at TP201 with respect to Input Lo. The voltage should be -12V, ±5% in the "LINE" mode of operation, and also in the "CHG" and "BAT" modes of operation if batteries are installed.

3. Battery Check. See Section 6-3a.

c. How To Calibrate the Instrument. For best accuracy, the Model 160B should be calibrated with the Model 1609 Cal. Cover Accessory or an equivalent. The instrument should be allowed to stabilize for approximately 1/2 hour after the Cal. Cover is put in place. It is important that the calibration sequence be followed exactly, because the adjustments are interrelated and dependent on prior calibration steps.

d. DC Voltage Calibration.

1. Voltage Zero and Offset Current Zero Adjustment.

a). Select 1mV range.

b). Place a short (low-thermal copper) across the input terminals.

c). Connect Voltmeter (I) to the Model 160B Analog Output.

d). Adjust front panel Zero Control (R114) for a reading of ±0.3mV at Voltmeter (I).

e). Remove the short across the Model 160B input terminals.

f). Adjust Offset Current Zero (R121) for a reading of ±20mV at Voltmeter (I).

NOTE

There is a long time constant for this adjustment due to the 10MΩ input impedance and the 0.56μF filter capacitor.

2. Display Zero and Rectifier Zero Adjustment.

a). Select 100mV Range on Model 160B.

b). Connect Voltage Source (J) to Divider (K).

c). Set Voltage Source (J) for 1V, and set Divider (K) for 0.001 ratio.

d). Apply a +1mV signal to the Model 160B input.

e). Adjust Display Zero (R136) for a reading of +01.0 at the Model 160B display.

f). Apply a -1mV signal.

g). Adjust Rectifier Zero (R135) for a reading of -01.0 at the Model 160B display.

NOTE

It may be necessary to repeat steps d, e, f, and g one or more times.

3. +DC Cal. and -DC Cal. Adjustment.

a). Change Divider (K) setting to 0.1 ratio.

b). Apply a +100mV signal to the Model 160B input.

c). Adjust +DC Cal. (R137) for a reading of +100.0 at the Model 160B display.

d). Apply a -100mV signal.

e). Adjust -DC Cal. (R134) for a reading of -100.0 at the Model 160B display.

NOTE

If the readings at full-range are considerably "out" before adjustment, then steps 2 and 3 should be repeated.

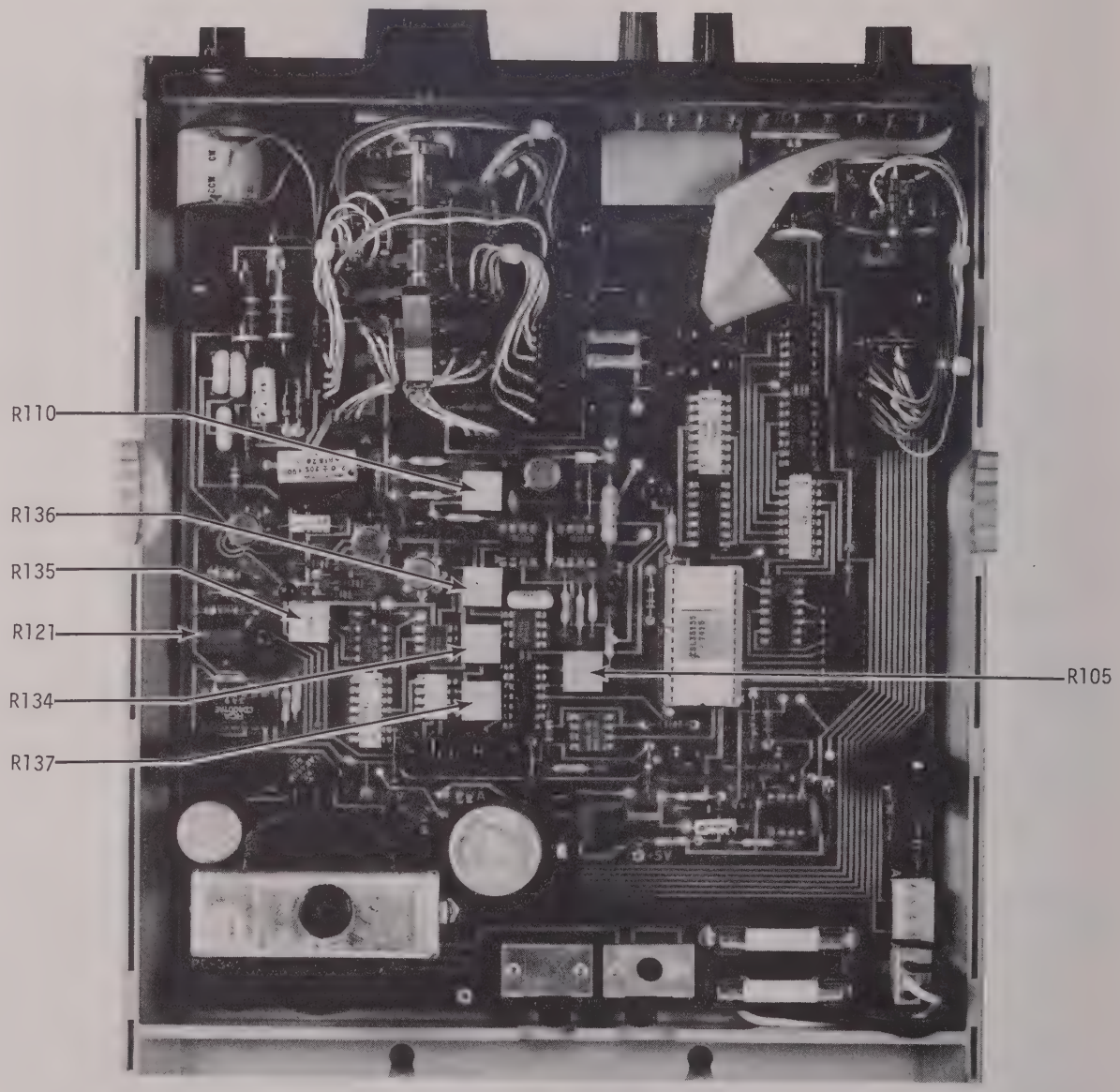


FIGURE 30. Location of Calibration Adjustments.

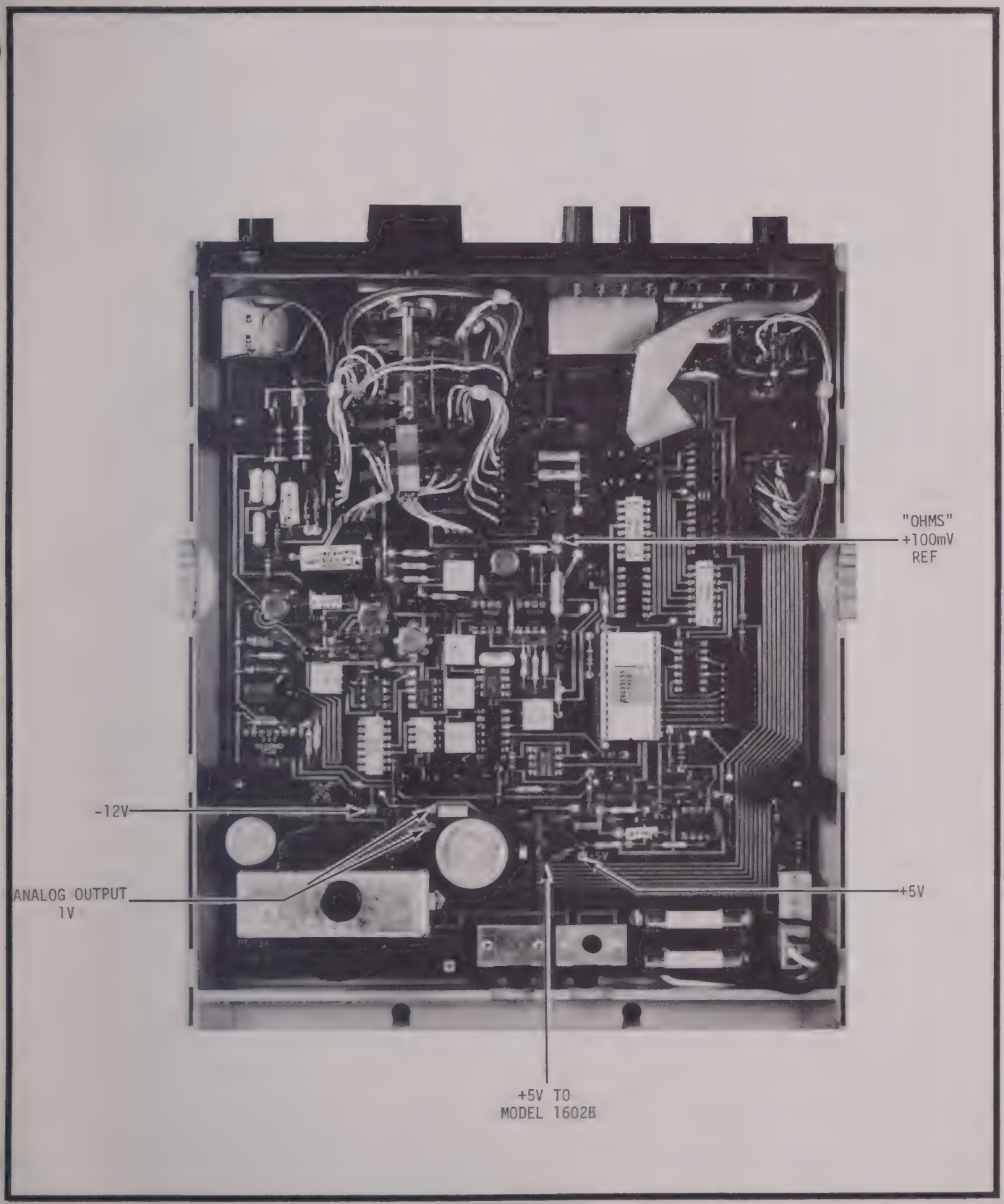


FIGURE 31. Location of Test Points.

e. Ohms Calibration.

1. 100mV Reference Adjustment.

a). Leave the Model 160B set on the 100mV Range;;leave Voltage Source (J) and Divider (K) connected to the Model 160B input.

b). Set Voltage Source (J) to 0V, and set Divider (K) to "0" output.

c). Connect Voltmeter (I) to TP101 (100mV Ref),

d). Adjust the "100mV Adj." trimpot (R105) for +100mV, ±20μV at Voltmeter (I).

2. Ohms Reference Accuracy Adjustment.

a). Set Voltage Source (J) to 2V, and set Divider (K) to 0.1 ratio.

b). Apply a +200mV to the Model 160B input.

c). Adjust the "Ohms Ref. Accuracy" trimpot (R110) for +300mV, ±60μV at Voltmeter (I).

TABLE 6-7.
Summary of Calibration Adjustments

Source Input	Source Accuracy	Range	Display Reading	Test Equipment Desig.	Test Equipment Reading	Adjustment Name and Circuit Desig.
Low-Thermal short	--	1 mV	--	(I)	Analog Output set to 0 ± .3mV	Front Panel Zero (R114)
Open	--	1 mV	--	(I)	Analog Output set to 0 ± 20mV	Offset Current Zero (R121)
+1mV	±.5%	100 mV	+01.0	--	--	Display Zero (R136)
-1mV	±.5%	100 mV	-01.0	--	--	Rectifier Zero (R135)
+100mV	±.01%	100 mV	+100.0	--	--	+DC Cal. (R137)
-100mV	±.01%	100 mV	-100.0	--	--	-DC Cal. (R134)
Short	--	100 mV	--	(I)	TP101 set to +100mV ± 20μV	100mV adj. (R105)
+200mV	±.01%	100 mV	--	(I)	TP101 set to +300mV ± 60μV	Ohms Ref. Accuracy (R110)

TABLE 6-8*.
Accuracy Check for DC Voltage

Range	Tolerance on Reading	Principle Component Involved
1 mV	±1-1/2 digits	Resistor Network R160
10 mV	±1-1/2 digits	Resistor Network R160
100 mV	±1-1/2 digits	Resistor Network R160
1 V	±1-1/2 digits	Resistor Network R159
10 V	±1-1/2 digits	Resistor Network R159
100 V	±1-1/2 digits	Resistor Network R159
1000 V	±1-1/2 digits	Resistor Network R159

*This table is to be considered as an extension of Table 6-3. The modified "Tolerance on Reading" column shown here allows the user to verify that the instrument will meet published specs for a period of 6 months.

TABLE 6-9*.
Accuracy Check for Resistance

Range	Tolerance on Reading	Principle Component Involved
1 Ω	±3-1/2 digits	R147 (99.9Ω)
10 Ω	±3 digits	R147 (99.9Ω)
100 Ω	±3 digits	R147 (99.9Ω)
1 kΩ	±3 digits	R148 (1kΩ)
10 kΩ	±3 digits	R149 (10kΩ)
100 kΩ	±3 digits	R150 (100kΩ)
1 MΩ	±3 digits	R151 (1MΩ)
10 MΩ	±3 digits	R152 (10MΩ)
100 MΩ	±90 digits	R153 (100MΩ)
1000 MΩ	±250 digits	R154 (910MΩ)

*This table is to be considered as an extension of Table 6-4. The modified "Tolerance on Reading" column shown here allows the user to verify that the instrument will meet published specs for a period of 6 months.

TABLE 6-10*.
Accuracy Check for Current

Range	Tolerance on Reading	Principle Component Involved
10 nA	±4 digits	R145 (1MΩ)
100 nA	±2-1/2 digits	R146 (100kΩ)
1 µA	±2-1/2 digits	R139 (10kΩ) and CR108
10 µA	±2-1/2 digits	R140 (1kΩ)
100 µA	±2-1/2 digits	R141 (100Ω)
1 mA	±2-1/2 digits	R142 (10Ω)
10 mA	±2-1/2 digits	R143 (0.997Ω)
100 mA	±3-1/2 digits	R144 (0.0987Ω) and R163** (20Ω)
1000 mA	±3-1/2 digits	R144 (0.0987Ω) and R163** (20Ω)

*This table is to be considered as an extension of Table 6-5. The modified "Tolerance on Reading" column shown here allows the user to verify that the instrument will meet published specs for a period of 6 months.

**R163 may or may not be installed. See schematic 26590E.

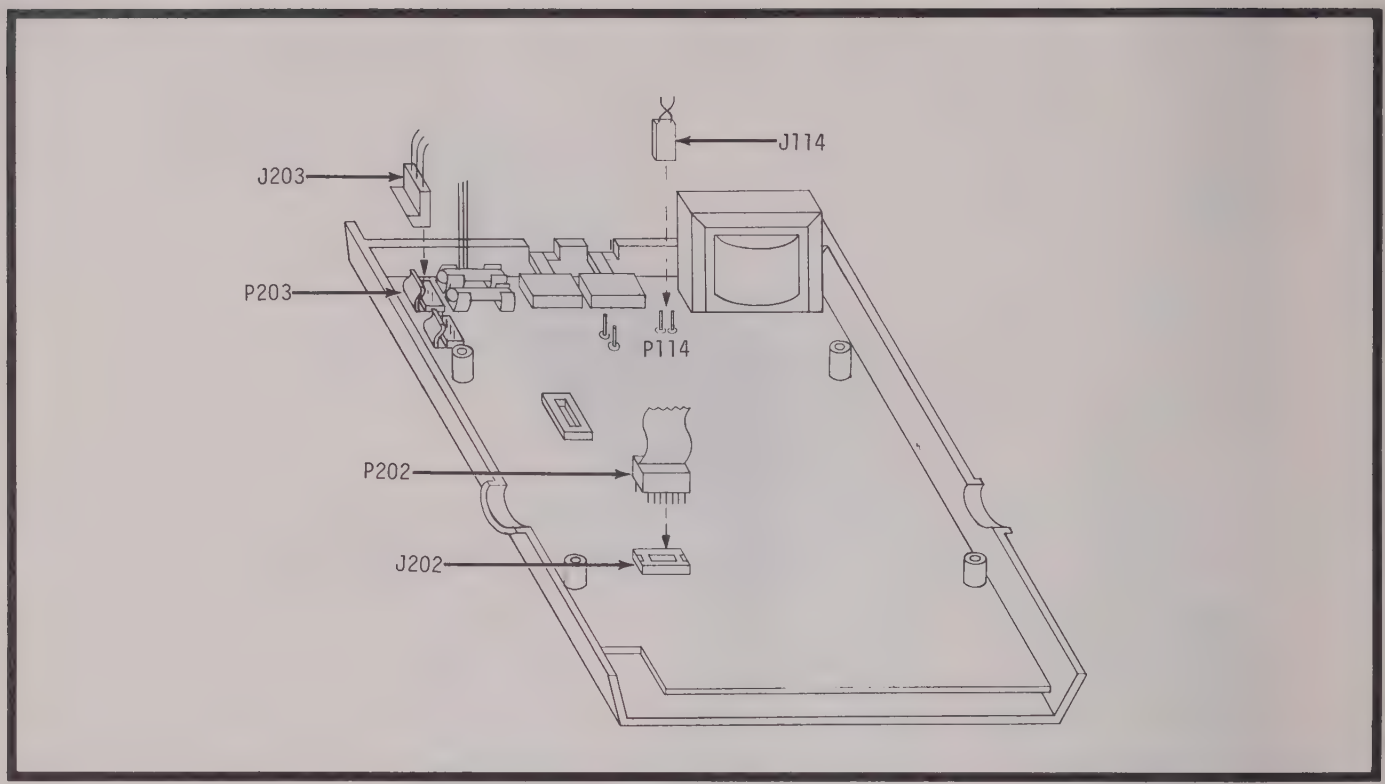


FIGURE 32. Location of Chassis Connections.

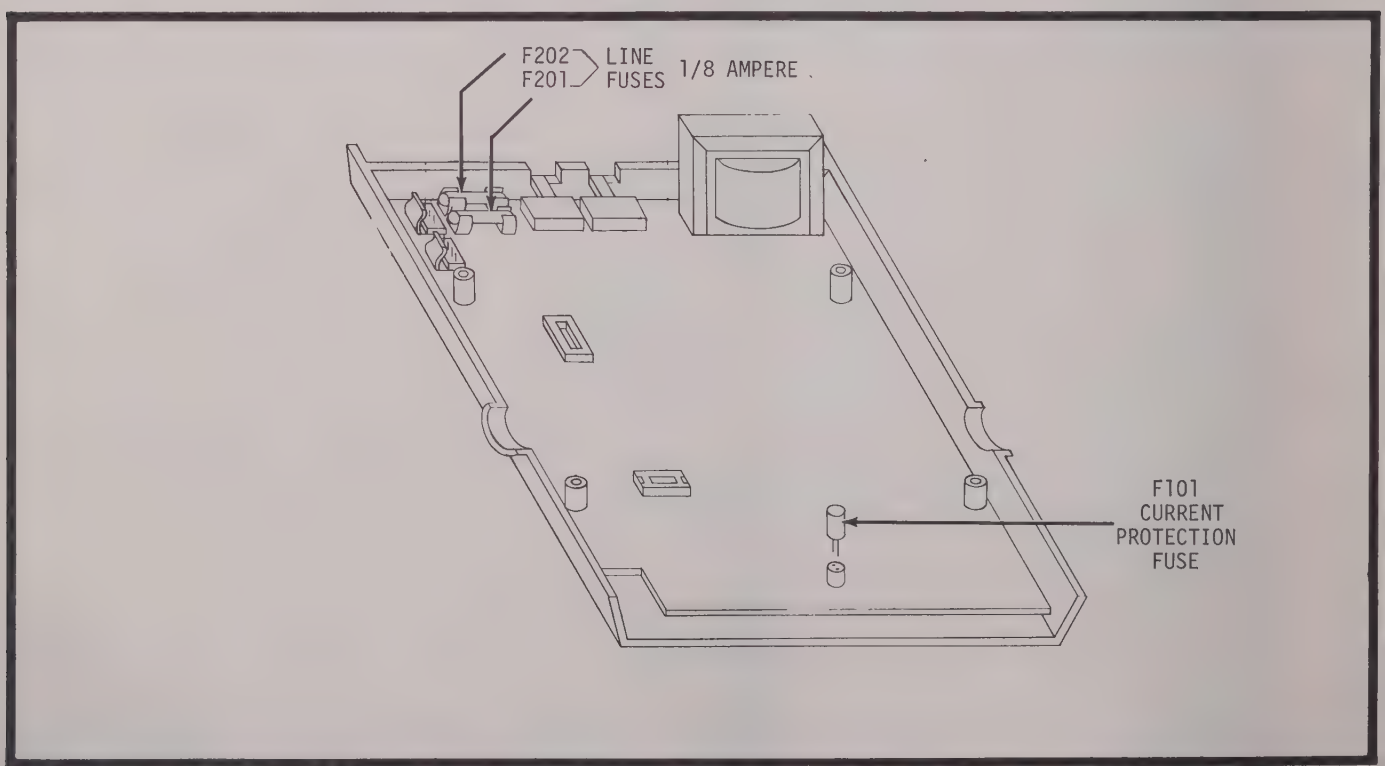


FIGURE 33. Location of Fuses.

SECTION 7. REPLACEABLE PARTS

7-1. GENERAL. This section contains information for ordering replacement parts. The parts list is arranged in alphameric order of their Circuit Designations.

7-2. ORDERING INFORMATION. To place an order or to obtain information concerning replacement parts, contact your Keithley representative or the factory. See the inside front cover of the manual for addresses. When ordering, include the following information:

a. Instrument Model Number

b. Instrument Serial Number

c. Part Description

d. Circuit Designation (if applicable)

e. Keithley Stock Part Number.

7-3. SCHEMATICS.

a. Input Amplifier and A/D Converter - (26590E). This schematic describes the input amplifier, range switching, and A/D Converter circuitry. Circuit designation series is "100".

b. Digital Logic, Display and Power Supply - (26584E). This schematic describes the display drive and power supply circuitry. Circuit designation series is "200".

c. Model 1602B Digital Output - (26654E). This schematic describes the digital output for Model 160B. Circuit designation series is "300".

TABLE 7-1.
Abbreviations, Symbols, and Designators

A, a	ampere
A	assembly
BT	battery
C	capacitor
CbVar	carbon variable
Cer D	ceramic disc
cer T	ceramic trimmer
Coef	coefficient
com	common
comp	composition
DCb	deposited carbon
Desig	designation
D	diode (all types)
DPDT	double-pole double-throw
DPST	double-pole single-throw
DS	lamp
elect	electrolytic
encap	encapsolated
EAL	electrolytic, aluminum
ETB	electrolytic, tubular
ETT	electrolytic, tantalum
F	farad (μF = 10^{-6} farad)
FET	field effect transistor
fempto	10^{-15}
FL	filter
fxd	fixed
Fig	figure
F	fuse
GaAs	gallium arsenide
GCb	glass enclosed carbon
Ge	germanium
grd	ground
H	henry (μH = 10^{-6} henry)
Hg	Mercury
Hz	hertz (cycles per second)
ID	inside diameter
in	inches (1 in = 25.4 mm)
J	jack
k	kilo (10^3)
kΩ	kilohm (10^3 ohms)
kHz	kilohertz (10^3 Hz)
K	relay
L	inductor
lin	linear
log	logarithmic
LSI	large scale integrated circuit
M	meter or Meg (10^6)
m	milli (10^{-3})
Meg	megohm ($10^6\Omega$)
mA	milliamperes (10^{-3}A)
mS	millisecond (10^{-3} seconds)
MΩ	megohm ($10^6\Omega$)
MtF	metal film
mfr	manufacturer
mtg	mounting
My	Mylar
nA	nanoampere (10^{-9}A)
no	number
NC	normally closed
NO	normally open
Ω	ohms
obd	order by description
OD	outside diameter
p	pico (10^{-12})
p	peak
pc	printed circuit
pF	picofarad (10^{-12} farad)
piv	peak inverse voltage
P	plug
poly	polystyrene
pot	potentiometer (variable resistor)
p-p	peak-to-peak
ppm	parts per million
Q	transistor
QA	integrated circuit (all types)
R	resistor
ref	reference
RN	resistor network
rms	root-mean-square
S	switch
SPDT	single-pole double-throw
SPST	single-pole single-throw
T	transformer
Tan	tantalum
TC	temperature coefficient
tol	tolerance
trim	trimmer
V	volt or vacuum tube (all types)
vac	volts; alternating current
vdc	volts, direct current
W	watt
ww	wirewound

TABLE 7-2.
Cross-Reference of Manufacturers

ABREV.	NAME AND ADDRESS
A-B	Allen-Bradley Corp. Milwaukee, WI. 53204
AMPRX	Amperex Elkgrove Village, IL. 60007
AMP	Amp Inc. Elizabethtown, PA. 17022
A-D	Analog Devices, Inc. Cambridge, MA. 02142
BECK	Beckman Instruments, Inc. Fullerton, CA. 92634
BERG	Berg Electronics, Inc. New Cumberland, PA. 17070
BOURN	Bourns, Inc. Riverside, CA. 92507
BUSS	Bussmann Mfg. Div. St. Louis, MO.
CENLB	Centralab Division Milwaukee, WI. 53201
CLARO	Clarostat Mfg. Co., Inc. Dover, NH. 03820
COMPI	Components, Inc. Biddeford, ME. 04005
C-W	Continental-Wirt Electronics Corp. Philadelphia, PA.
CTS	CTS Corporation Elkart, IN. 46514
DALE	Dale Electronics, Inc. Columbus, NB. 68601
DICK	Dickson Electronics, Corp. Scottsdale, AZ. 85052
ECI	Electrocube Inc. San Gabriel, CA. 91776
EDI	Electronic Devices, Inc. Yonkers, NY. 10710
ERIE	Erie Technological Products, Inc. Erie, PA. 16512
FAIR	Farichild Instruments Corp. Mountain View, CA. 94040
GE	General Electric Company Syracuse, NY. 13201
GENI	General Instrument Corp. Newark, NJ. 07104
H-P	Hewlett-Packard Palo Alto, CA. 94304
INTER	Intersil, Inc. Cupertino, CA. 95014
IRC	IRC Division Burlington, IA. 52601
CAN	ITT Cannon Electric Santa Ana, CA. 92701
KI	Keithley Instruments, Inc. Cleveland, OH. 44139
LITFU	Littlefuse Inc. Des Plaines, IL. 60016
MOLEX	Molex Douners Grove, IL. 60515
MOT	Motorola Semiconductor Products, Inc. Phoenix, AZ. 85008
NAT	National Semiconductor Corp. Santa Clara, CA. 95051
RCA	RCA Corporation Comerville, NJ. 08876
RCL	RCL Electronics, Inc. Manchester, NH. 03102
SIG	Signetics Corp. Sunnyvale, CA. 94086
SIEM	Siemens Corporation Iselin, NJ. 08830
TEMPL	Temple Tecate, CA. 92080
TEXAS	Texas Instruments, Inc. Dallas, TX. 75231
VISH	Vishay Resistor Products Malvern, PA. 19355

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C101	2200 pF, 500V, CerD	ERIE	831Z5U0222M	C22-2200P	1
C102	100 pF, 1000V, CerD.	CENLB	DD-101	C64-100P	1
C103	0.1 µF, 250V, MTF.	AMPRX	C280AE/P100K	C128-0.1M	3
C104	0.56 µF, 50V, MPC	ECI	625B1A474	C201-0.56M	1
C105	0.01 µF, 250V, MtF.	AMPRX	C280AE/P10K	C178-.01M	1
C106	0.0022µF, 200V, MPCb.	ECI	625B1C	C221-.0022M	2
C107	0.1 µF, 250V, MTF.	AMPRX	C280AE/P100K	C178-0.1M	..
C108	100 pF, 630V, Poly	SIEM	B31360A1101H	C252-100P	2
C109	100 pF, 630V. Poly	SIEM	B31360A1101H	C252-100P	..
C110	0.0022µF, 200V, MPCb.	ECI	625B1C222	C221-.0022M	..
C111	2 µF, 50V, MPC	ECI	625B1A205	C215-2M	1
C112	10 pF, 1000V, CerD.	CENLB	DD-100	C64-10P	1
C113	10 µF, 20V, ETT	COMPI	TSD220106	C179-10M	3
C114	10 µF, 20V, ETT	COMPI	TSD220106	C179-10M	..
C115	39 µF, 15V, Epoxy	COMPI	TD4-015-396-10	C228-39M	4
C116	39 µF, 15V, Epoxy	COMPI	TD4-015-396-10	C228-39M	..
C117	22 µF, 20V, ETT	COMPI	TD1-20-226-20	C179-22M	2
C118	22 µF, 20V, ETT	COMPI	TD1-20-226-20	C179-22M	..
C119	39 µF, 15V, Epoxy	COMPI	TD4-015-396-10	C228-39M	..
C120	0.1 µF, 250V, MTF.	AMPRX	C280AE/P100K	C178-0.1M	..
C201	0.01 µF, 200V, My	ECI	210B1C103-2%	C247-0.01M	1
C202	0.01 µF, 500V, CerD	ERIE	871-Z5U0-103M	C22-0.01M	1
C203	2000 µF, 25V, EAL	RICH	JC-P-2000-25-8P	C255-2000M	1
C204	39 µF, 15V, Epoxy	COMPI	TD4-015-396-10	C228-39M	..
C205	Not Used.	.....	.....	.....	..
C206	400 µF, 50V, EAL	TEMPL	411-400µF	C246-400M	1
C207	10 µF, 20V, ETT	COMPI	TD2-20-106-20	C179-10M	..

DIODES

CR101	Rectifier, 1A, 800V	MOT	1N4006	RF-38	3
CR102	Computer Type, 75mA, 75V.	TEXAS	1N914	RF-28	3
CR103	Rectifier, 1A, 800V	MOT	1N4006	RF-38	..
CR104	Rectifier, 1A, 800V	MOT	1N4006	RF-38	..
CR105	Rectifier, 150mA, 125V.	FAIR	1N3595	RF-43	1
CR106	Computer Type, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR107	Not Used.	.....	.....	.....	..
CR108	Bridge Rectifier, 4-diode, 50V, 5A.	EDI	PE05	RF-48	1
CR201	Computer Type, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR202	Computer Type, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR203	Rectifier, Bridge Type, 1.5A, 400V.	EDI	PF40	RF-46	2
CR204	Rectifier, Bridge Type, 1.5A, 400V.	EDI	PF40	RF-46	..

DISPLAYS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
DS201	Digital Display, Polarity-Overflow.	H-P	5082-7732*	DD-11*	1
DS202	Digital Display, Seven-Segment.	H-P	5082-7730*	DD-9*	3
DS203	Digital Display, Seven-Segment.	H-P	5082-7730*	DD-9*	..
DS204	Digital Display, Seven-Segment.	H-P	5082-7730*	DD-9*	..

*Selected for light intensity, "C", "D", or "E".

FUSES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
F101	Fuse, 3A, Microfuse	LITFU	273003	FU-43	1
F201	Fuse, 1/8A, 250V, 3AB, Slo-Blo.	BUSS	MDL-1/8A	FU-20	2
F202	Fuse, 1/8A, 250V, 3AB, Slo-Blo.	BUSS	MDL-1/8A	FU-20	..
F203	Fuse, 1A, 250V.	BUSS	MDL-1A	FU-10	2
F204	Fuse, 1A, 250V.	BUSS	MDL-1A	FU-10	..

CONNECTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
J101	Housing, Female, 3 pin	BERG	65039-034	CS-270	3
J102	Housing, Female, 2 pin	BERG	65039-035	CS-266	2
J103	Housing, Female, 1 pin	BERG	47439	CS-236	1
J104	Housing, Female, 5 pin	BERG	20370	CS-251	6
J105	Housing, Female, 10 pin.	BERG	20052	CS-237	3
J106	Housing, Female, 5 pin	BERG	20370	CS-251	..
J107	Housing, Female, 5 pin	BERG	20370	CS-251	..
J108	Housing, Female, 5 pin	BERG	20370	CS-251	..
J109	Housing, Female, 5 pin	BERG	20370	CS-251	..
J110	Housing, Female, 3 pin	BERG	65039-034	CS-270	..
J111	Housing, Female, 5 pin	BERG	20370	CS-251	..
J112	Binding Post, Black.	BERG		BJ-6B	1
J113	Binding Post, Red.	BERG		BJ-6R	1
J114	Housing, Female, 3 pin	BERG	65039-034	CS-270	..
J115	Binding Post, Red.	KI	.....	25537A	1
J116	Binding Post, Black.	KI	.....	25539A	1
J206	Housing, Female, 10 pin.	BERG	20052	CS-237	..
J207	Housing, Female, 10 pin.	BERG	20052	CS-237	..
J208	Housing, Female, 2 pin	BERG	65039-035	CS-266	..
P101	Male, 3-pins	KI	.....	CS-339-3	2
P102	Male Pin (2)	KI	.....	24249A	..
P103	Male Pin (1)	KI	.....	24249A	..
P104	Male Pin (3)	KI	.....	24249A	..
P105	Male, 10-pins.	KI	.....	CS-339-10	1
P106	Male, 4-pins	KI	.....	CS-339-4	2
P107	Male, 5-pins	KI	.....	CS-339-5	2
P108	Male, 5-pins	KI	.....	CS-339-5	
P109	Male Pin (3)	KI	.....	24249A	..
P110	Male, 3-pins	KI	.....	CS-339-3	..
P111	Male, 4-pins	KI	.....	CS-339-4	..
P112	Not Used	.....	.....	.....	..
P113	Not Used	.....	.....	.....	..
P114	Male Pin (2)	KI	.....	24249A	..
P201	Cable Assembly to Model 1602B.	KI	.....	26424A-2	1
P202	Cable Assembly to Display Board.	KI	.....	26424A-1	1
P203	Receptacle, Male, 3 pins	MOLEX	A239-3A	CS288-3	1
P204	Line Cord, 3 conductor, 5 FT, 9 IN	KI	.....	CO-9	1
P205	Receptacle, Male, 4 pins	MOLEX	A2391-4A	CS288-4	1
P206	Male, 8-pins	KI	.....	CS-339-8	2
P207	Male, 8-pins	KI	.....	CS-239-8	..
P208	Male Pin (2)	KI	.....	24249A	..

TRANSISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q101	PNP, Power Type, 10W, TO-5 Case	RCA	2N5416	TG-105	1
Q102	Dual "P" Chan, MOS FET, TO-77 Case.	GENI	955-004	TG-94	1
Q103	"N" Chan, JFET, R-110 Case.	INTER	ITE4392	TG-76	1
Q104	PNP, TO-106 Case.	FAIR	2N5139	TG-66	2
Q105	PNP, TO-106 Case.	FAIR	2N5140	TG-110	1
Q106	NPN, TO-106 Case.	FAIR	2N3565	TG-39	1
Q201	PNP, TO-106 Case.	FAIR	2N5139	TG-66	..
Q202	PNP, TO-106 Case.	FAIR	2N4355	TG-90	4
Q203	PNP, TO-106 Case.	FAIR	2N4355	TG-90	..
Q204	PNP, TO-106 Case.	FAIR	2N4355	TG-90	..
Q205	PNP, TO-106 Case.	FAIR	2N4355	TG-90	..
Q206	NPN, TO-92 Case	MOT	2N5089	TG-62	2
Q207	NPN, TO-92 Case	MOT	2N5089	TG-62	..

RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R101	1kΩ, 10%, 0.25W, Comp	A-B	CB-102-10%	R76-1K	4
R102	499kΩ, 0.5%, 0.5W, MtF.	DALE	MMF-1/2-T9-499K	R171-499K	1
R103	1.8kΩ, 10%, 0.25%, Comp	A-B	CB-182-10%	R76-1.8K	1
R104	499kΩ, 1%, 0.12W, MtF	DALE	MFF-1/8-T9-499K	R177-499K	2
R105	1kΩ, 0.5W, Var.	BECK	72PMR-1K	RP97-1K	2
R106	5.8kΩ, 1%, 0.12W, MtF	DALE	MFF-1/8-T9-5.8K	R177-5.8K	1
R107	100Ω, 1%, 0.12W, MtF.	DALE	MFF-1/8-T9-100	R177-100	1
R108	499kΩ, 1%, 0.12W, MtF	DALE	MFF-1/8-T9-499K	R177-499K	..
R109	475kΩ, 1%, 0.12W, MtF	DALE	MFF-1/8-T9-475K	R177-475K	1
R110	50kΩ, 0.5W, Var	BECK	72PMR-50K	RP97-50K	1
R111	56.2kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-56.2K	R88-56.2K	1
R112	100kΩ, 1%, 0.12W, MtF	IRC	CEA-TO-100K	R88-100K	1
R113	32.4kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-32.4K	R88-32.4K	1
R114	50kΩ, 2W, Var	CLARO	73JA-50KΩ	RP108-50K	1
R115	1MΩ, 1%, 0.12W, MtF	IRC	CEA-TO-1MΩ	R88-1M	1
R116	56kΩ, 10%, 2W, Comp	A-B	HB-563-10%	R3-56K	2
R117	56kΩ, 10%, 2W, Comp	A-B	HB-563-10%	R3-56K	..
R118	22kΩ, 10%, 0.25W, Comp.	A-B	CB-223-10%	R76-22K	3
R119	330Ω, 10%, 0.25W, Comp.	A-B	CB-331-10%	R76-330	2
R120	330Ω, 10%, 0.25W, Comp.	A-B	CB-331-10%	R76-330	..
R121	2kΩ, 0.5W, Var.	BOURN	32991-2K	RP104-2K	1
R122	9.0kΩ, 0.1%, 0.12W, MtF	DALE	MFF-1/8-9.0KΩ	R-168-9.0K	1
R123	10kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-10KΩ	R88-10K	1
R124	2.2MΩ, 10%, 0.25W, Comp	A-B	CB-222-10%	R76-2.2M	2
R125	1kΩ, 10%, 0.25W, Comp	A-B	CB-102-10%	R76-1K	..
R126	2.2MΩ, 10%, 0.25W, Comp	A-B	CB-225-10%	R76-2.2M	..
R127	5.6kΩ, 10%, 0.25W, Comp	A-B	CB-562-10%	R76-5.6K	1
R128	22kΩ, 10%, 0.25W, Comp.	A-B	CB-223-10%	R76-22K	..
R129	22kΩ, 10%, 0.25W, Comp.	A-B	CB-223-10%	R76-22K	..
R130	4.99kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-4.99K	R88-4.99K	1
R131	12.1kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-12.1K	R88-12.1K	1
R132	1kΩ, 10%, 0.25W, Comp	A-B	CB-102-10%	R76-1K	..
R133	3.3kΩ, 10%, 0.25W, Comp	A-B	CB-332-10%	R76-3.3K	2
R134	500Ω, 0.5W, Var	BECK	72PMR-500	RP97-500	1
R135	10kΩ, 0.5W, Var	BECK	72PMR-10K	RP97-10K	2
R136	10kΩ, 0.5W, Var	BECK	72PMR-10K	RP97-10K	..
R137	1kΩ, 0.5W, Var.	BECK	72PMR-1K	RP97-1K	..
R138	2kΩ, 1%, 0.12W, MtF	IRC	CEA-TO-2K	R88-2K	1
R139	10kΩ, 0.02%, 0.3W, MtF.	VISH	V53-10kΩ	R183-10K	2
R140	1kΩ, 0.1%, 0.5W, MtF	DALE	MFF-1/2-1K	R-169-1K	1
R141	100Ω, 0.1%, 0.12W, MtF.	DALE	MFF-1/8-100	R168-100	1
R142	10.0Ω, 0.1%, 5W	RCL	T5-10.0	R185-10.0	1
R143	0.997Ω, 0.1%, 5W.	RCL	T5-0.997	R185-0.997	1

RESISTORS (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R144	0.0987Ω, 0.1%, 5W	RCL	T5-0.0987	R185-0.0987	1
R145	1MΩ, 0.1%, 0.5W, MtF.	DALE	MFF-1/2-T9-1M	R169-1M	2
R146	100kΩ, 0.1%, 0.5W, MtF.	DALE	MFF-1/2-T9-100K	R169-100K	2
R147	99.9Ω, 0.1%, 0.12W, MtF	DALE	MFF-1/8-99.9	R168-99.9	1
R148	1kΩ, 0.1%, 0.12W, MtF	DALE	MFF-1/8-1K	R168-1K	1
R149	10kΩ, 0.1%, 0.12W, MtF.	DALE	MFF-1/8-10K	R168-10K	..
R150	100kΩ, 0.1%, 0.5W, MtF.	DALE	MFF-1/2-100K	R169-100K	..
R151	1MΩ, 0.1%, 0.5W, MtF.	DALE	MFF-1/2-1M	R169-1M	..
R152	10MΩ, 0.1%, 0.5W.	DALE	HMF-10M	R174-10M	1
R153	99MΩ, 1%, 1W, Comp.	HIMEG	A-60-99M	R-235-99M	1
R154	910MΩ, 10%, 0.5W, Comp.	IRC	GBT-1/2-910	R230-910M	1
R155	1.74kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-1.74K	R88-1.74K	1
R156	Not Used.	.....	.....	.....	..
R157	27kΩ, 10%, 0.25W, Comp.	A-B	CB-273-10%	R76-27K	1
R158	47kΩ, 10%, 0.25W, Comp.	A-B	CB-473-10%	R76-47K	1
R159	Thick Film Network, 4-pins.	IRC	KE005	TF-34	1
R160	Thick Film Network, 5-pins.	IRC	KE003	TF-35	1
R161	Thick Film Network, 8-pin DIP	CTS	Special	TF-36	1
R162	Thick Film Network, 14-pin DIP.	CTS	Special	TF-37	1
R163	10Ω, 1%, 0.12W, MtF	IRC	CEA-TO-10	R88-10	1
R201	4.7kΩ, 10%, 0.25W, Comp	A-B	CB-472-10%	R76-4.7K	1
R202	2.2kΩ, 10%, 0.25W, Comp	A-B	CB-222-10%	R76-2.2K	1
R203	1kΩ, 10%, 0.25W, Comp	A-B	CB-102-10%	R76-1K	..
R204	3.3kΩ, 10%, 0.25W, Comp	A-B	CB-332-10%	R76-3.3K	..
R205	12.7kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-12.7K	R88-12.7K	1
R206	1kΩ, 1%, 0.12W, MtF	IRC	CEA-TO-1K	R88-1K	1
R207	150Ω, 10%, 0.25W, Comp.	A-B	CB-151-10%	R76-150	2
R208	150Ω, 10%, 0.25W, Comp.	A-B	CB-151-10%	R76-150	..
R209	180Ω, 10%, 0.25W, Comp.	A-B	CB-181-10%	R76-180	3
R210	180Ω, 10%, 0.25W, Comp.	A-B	CB-181-10%	R76-180	..
R211	180Ω, 10%, 0.25W, Comp.	A-B	CB-181-10%	R76-180	..
R212	6.04kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-6.04K	R88-6.04K	1
R213	4.02kΩ,1%, 0.12W, MtF	IRC	CEA-TO-4.02K	R88-4.02K	1
R214	10kΩ, 10%, 0.25W, Comp.	A-B	CB-103-10%	R76-10K	2
R215	10kΩ, 10%, 0.25W, Comp.	A-B	CB-103-10%	R76-10K	..
R216	40.2 Ω, 1%, 0.12W, MtF.	IRC	CEA-TO-40.2	R88-40.2	1
R217	Thick Film Network, 16-pin DIP.	CTS	900-6	TF-30	1
R218	Thick Film Network, 16-pin DIP.	CTS	900-7	TF-31	1

SWITCHES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
S101	Rotary Switch, RANGE.	KI	.....	SW-373	1
---	Knob, RANGE	KI	.....	KN-33	1
S201	Slide Switch, DPDT, Line Voltage.	C-W	GG350PCDPDT	SW-318	2
S202	Slide Switch, DPDT, Line Voltage.	C-W	GG350PCDPDT	SW-318	..
S203	Rotary Switch, Power Selector	KI	.....	SW-374	1
---	Knob, Power	KI	.....	KN-37	1
---	Knob, ZERO.	KI	.....	KN-36	1

MISCELLANEOUS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
T201	Transformer, Power Type	KI	.....	TR-156	1
TP101	Test Point.	KI	.....	24249A	3
TP201	Test Point.	KI	.....	24249A	..
TP202	Test Point.	KI	.....	24249A	..

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
U101	Operational Amplifier, 8-pin DIP.	NAT	LM308N	26426A	1
U102	Operational Amplifier, 8-pin DIP.	NAT	LM308N	IC-99	2
U103	COS/MOS, 14-pin DIP	RCA	CD4007AE	IC-100	1
U104	Operational Amplifier, 8-pin DIP.	NAT	LM308N	IC-99	..
U105	Operational Amplifier, 8-pin, TO-99 Case.	A-D	AD741K	IC-97	1
U106	Operational Amplifier, 8-pin DIP.	FAIR	Special	IC-77	3
U107	Operational Amplifier, 8-pin DIP.	FAIR	Special	IC-77	..
U108	Transistor Array, 14-pin DIP.	RCA	CA3086	IC-53	3
U109	Operational Amplifier, 8-pin DIP.	FAIR	Special	IC-77	..
U110	Operational Amplifier, 8-pin DIP.	NAT	LM301AN	IC-24	1
U201	Large-Scale IC 28-pin DIP	FAIR	Special	LSI-2	1
U202	Timing Circuit, 8-pin DIP	SIG	NE555V	IC-71	1
U203	Quad 2-Input Pos NAND, 14-pin DIP	TEXAS	SN7401N	IC-47	1
U204	Hex Buffer/Driver, 14-pin DIP	TEXAS	SN7417N	IC-101	1
U205	Transistor Array, 14-pin DIP.	RCA	CA3086	IC-53	..
U206	Transistor Array, 14-pin DIP.	RCA	CA3086	IC-53	..
U207	5V, Regulator TO-220 Case	MOT	MC7805CP	IC-93	1
U208	12V, Regulator TO-220 Case.	FAIR	UGH7812393	IC-60	1

ZENER DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
VR101	Zener, 6.4V, 400mW.	DICK	1N4577	DZ-51	1
VR102	Zener, 2.6V	TEXAS	1N702A	DZ-33	1

MODEL 1602B DIGITAL OUTPUT
"300" SERIES, PC-352.

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C301	0.1μF, 250V, MtF.	AMPRX	C280AE/P100K	C178-0.1M	1
C302	470pF, 1000V, CerD.	CENLB	DD-471	C64-470P	4
C303	470pF, 1000V, CerD.	CENLB	DD-471	C64-470P	..
C304	470pF, 1000V, CerD.	CENLB	DD-471	C64-470P	..
C305	470pF, 1000V, CerD.	CENLB	DD-471	C64-470P	..

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
CR301	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	10
CR302	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR303	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR304	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR305	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR306	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR307	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR308	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR309	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR310	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..

CONNECTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
J301	Not Used.	.....	.....	.....	..
J302	Digital Output, 37-pins	AMP	205209-1	CS-301	1
J303	Female, 5-pins.	BERG	65039-040	CS-251	1
P301	Cable Assembly (Custom)	KI	.....	26424A-2	1
P302	Mating Connector, Digital Output, 37-pins	CAN	DC-37B	CS-302	1
--	Connector Cover (Hood for P302)	CAN	DC-512K1-1	CS-300	1

TRANSISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q301	NPN, Case TO-92	MOT	2N5087	TG-62	20
Q302	NPN, Case TO-92	MOT	2N5087	TG-62	..
Q303	NPN, Case TO-92	MOT	2N5087	TG-62	..
Q304	NPN, Case TO-92	MOT	2N5087	TG-62	..
Q305	NPN, Case TO-92	MOT	2N5087	TG-62	..
Q306	NPN, Case TO-92	MOT	2N5087	TG-62	..
Q307	NPN, Case TO-92	MOT	2N5087	TG-62	..
Q308	NPN, Case TO-92	MOT	2N5087	TG-62	..
Q309	NPN, Case TO-92	MOT	2N5087	TG-62	..
C310	NPN, Case TO-92	MOT	2N5087	TG-62	..
C311	NPN, Case TO-92	MOT	2N5087	TG-62	..
C312	NPN, Case TO-92	MOT	2N5087	TG-62	..
C313	NPN, Case TO-92	MOT	2N5087	TG-62	..
C314	NPN, Case TO-92	MOT	2N5087	TG-62	..
C315	NPN, Case TO-92	MOT	2N5087	TG-62	..
C316	NPN, Case TO-92	MOT	2N5087	TG-62	..
C317	NPN, Case TO-92	MOT	2N5087	TG-62	..
C318	NPN, Case TO-92	MOT	2N5087	TG-62	..
C319	NPN, Case TO-92	MOT	2N5087	TG-62	..
C320	NPN, Case TO-92	MOT	2N5087	TG-62	..

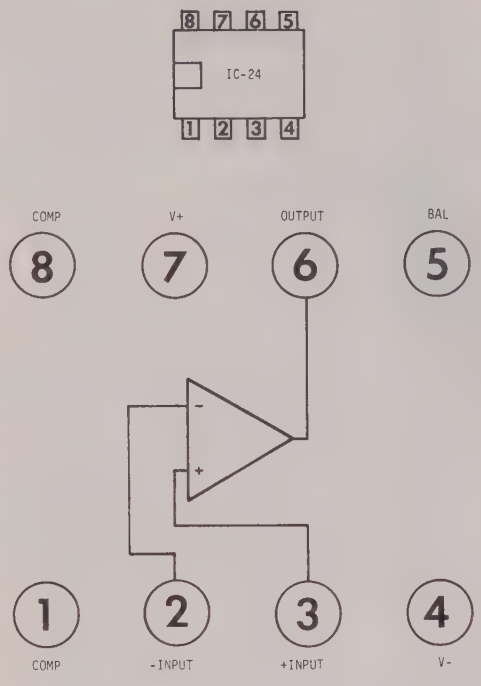
RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R301	100kΩ, 1%, 0.12W, MtF	IRC	CEA-TO-100kΩ	R88-100K	1
R302	10kΩ, 10%, 0.25W, Comp.	A-B	CB-103-10%	R76-10K	5
R303	Thick Film Network.	KI	.....	TF-39	4
R304	Thick Film Network.	KI	.....	TF-39	..
R305	Thick Film Network.	KI	.....	TF-39	..
R306	Thick Film Network.	KI	.....	TF-39	..
R307	10kΩ, 10%, 0.25W, Comp.	A-B	CB-103-10%	R76-10K	..
R308	10kΩ, 10%, 0.25W, Comp.	A-B	CB-103-10%	R76-10K	..
R309	10kΩ, 10%, 0.25W, Comp.	A-B	CB-103-10%	R76-10K	..
R310	10kΩ, 10%, 0.25W, Comp.	A-B	CB-103-10%	R76-10K	..

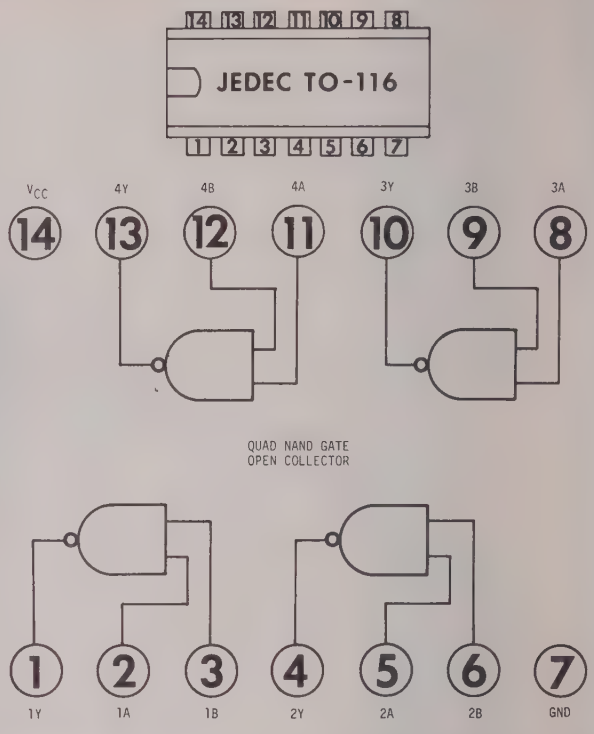
INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
U301	Hex Inverter, 16-pin DIP.	RCA	CD4049AE	IC-106	1
U302	Quad 2-input NOR, 14-pin DIP.	RCA	CD4001AE	IC-108	8
U303	Quad 2-input NOR, 14-pin DIP.	RCA	CD4001AE	IC-108	..
U304	Quad 2-input NOR, 14-pin DIP.	RCA	CD4001AE	IC-108	..
U305	Dual 4-Input NOR, 14-pin DIP.	RCA	CD4002AE	IC-105	1
U306	Timing Circuit, 8-pin DIP	SIG	NE555V	IC-71	1
U307	Quad 2-input NAND, 14-pin DIP	RCA	CD4011AE	IC-102	3
U308	Dual "D" Type, Flip-Flop, 14-pin DIP.	RCA	CD4013AE	IC-103	2
U309	Dual "D" Type, Flip-Flop, 14-pin DIP.	RCA	CD4013AE	IC-103	..
U310	Quad Clocked "D" Latch, 16-pin DIP.	RCA	CD4042AE	IC-104	3
U311	Quad Clocked "D" Latch, 16-pin DIP.	RCA	CD4042AE	IC-104	..
U312	Quad Clocked "D" Latch, 16-pin DIP.	RCA	CD4042AE	IC-104	..
U313	Hex Buffer, 16-pin DIP.	RCA	CD4050AE	IC-107	1
U314	Quad 2-input NOR, 14-pin DIP.	RCA	CD4001AE	IC-108	..
U315	Quad 2-input NOR, 14-pin DIP.	RCA	CD4001AE	IC-108	..
U316	Quad 2-input NOR, 14-pin DIP.	RCA	CD4001AE	IC-108	..
U317	Quad 2-input NOR, 14-pin DIP.	RCA	CD4001AE	IC-108	..
U318	Quad 2-input NOR, 14-pin DIP.	RCA	CD4001AE	IC-108	..
U319	Quad 2-input NAND, 14-pin DIP	RCA	CD4011AE	IC-102	..
U320	Quad 2-input NAND, 14-pin DIP	RCA	CD4011AE	IC-102	..

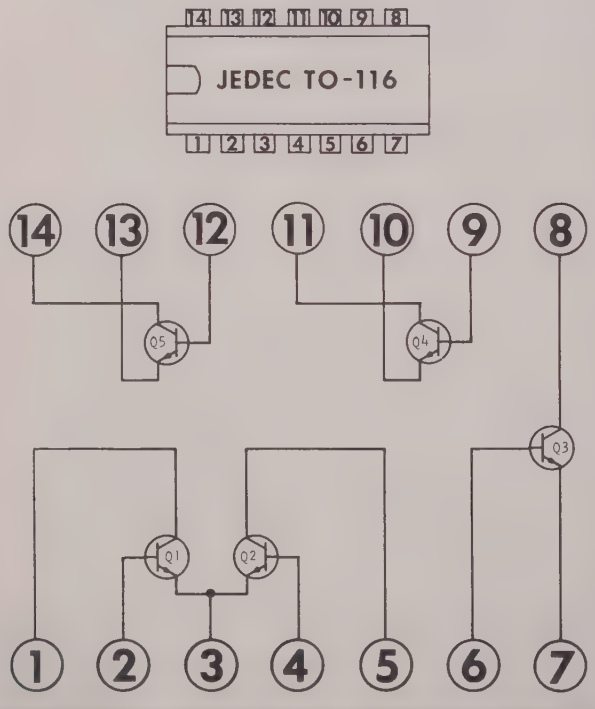
KEITHLEY PART NO. IC-24



KEITHLEY PART NO. IC-47



KEITHLEY PART NO. IC-53



KEITHLEY PART NO. IC -60 -93

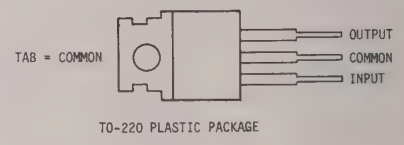


FIGURE 34. Case Outline - Integrated Circuits.

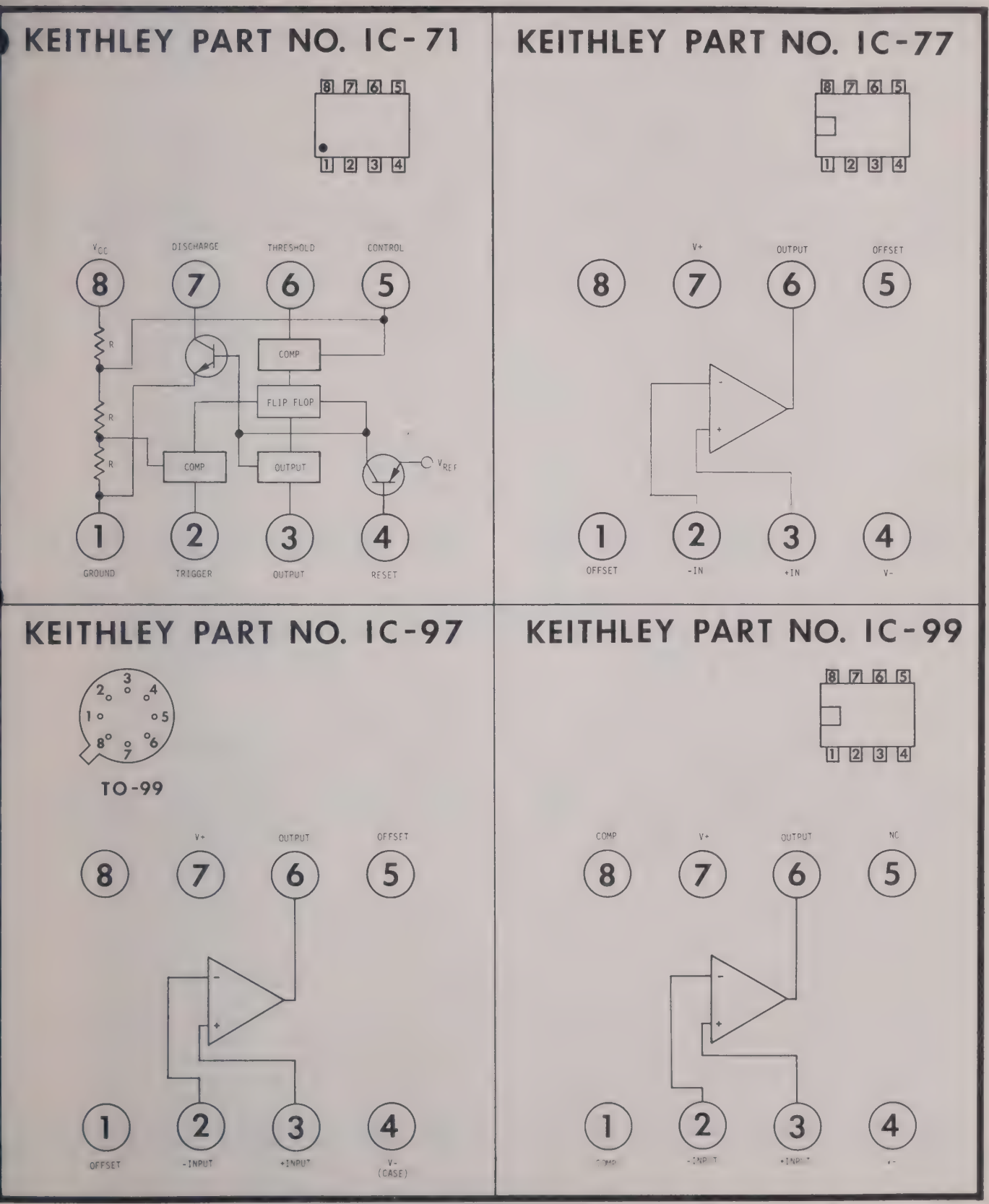


FIGURE 35. Case Outline - Integrated Circuits.

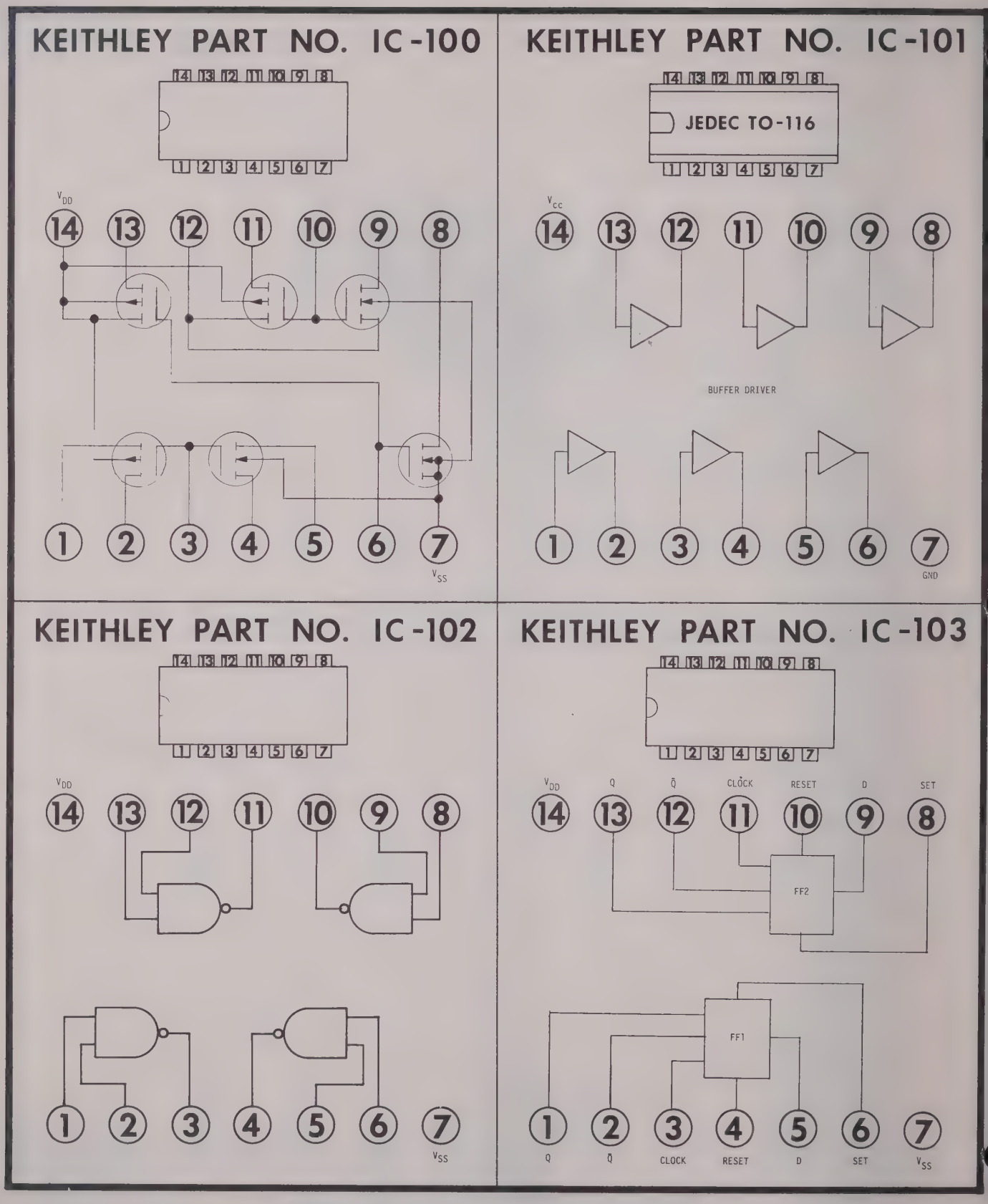


FIGURE 36. Case Outline - Integrated Circuits.

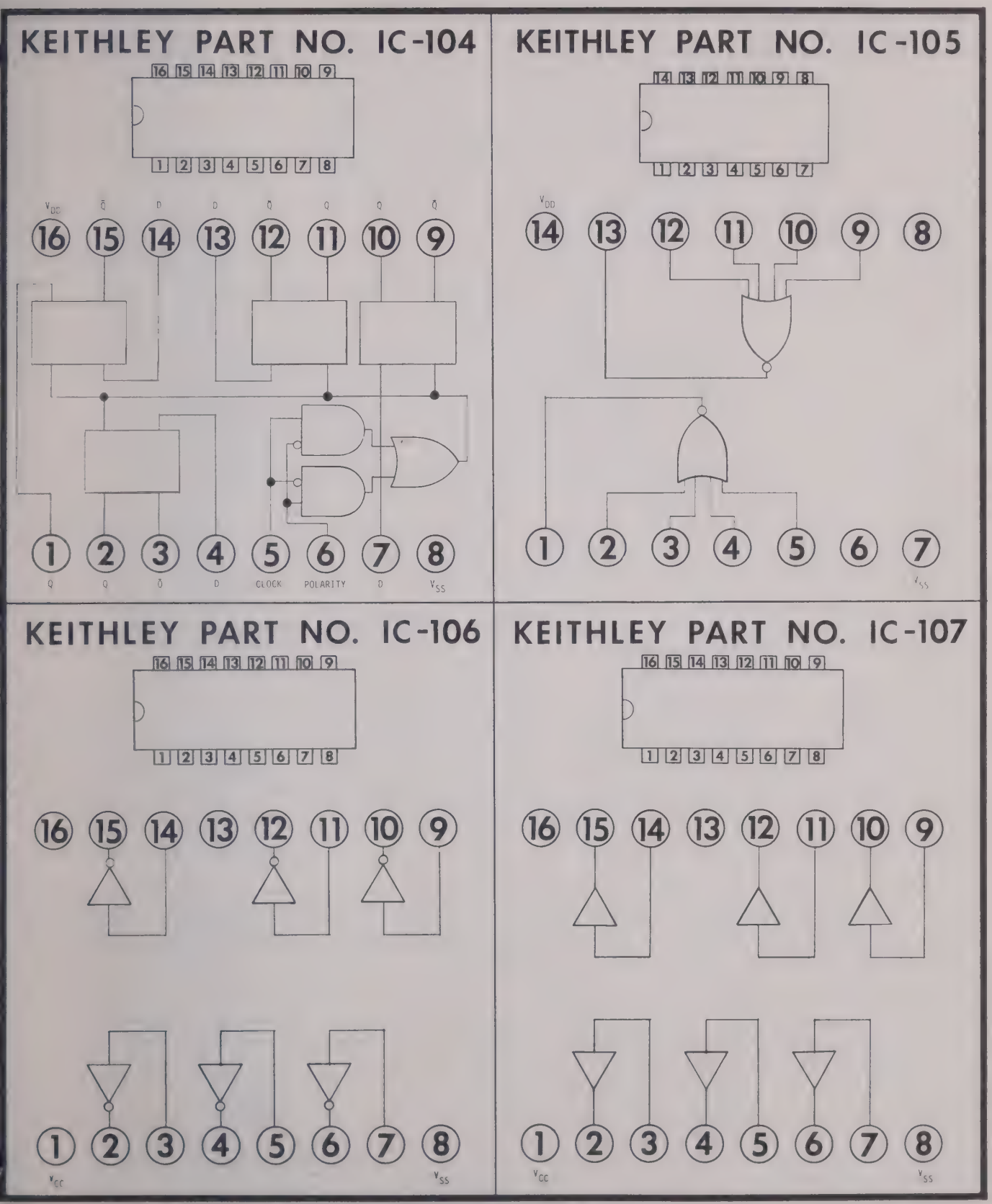
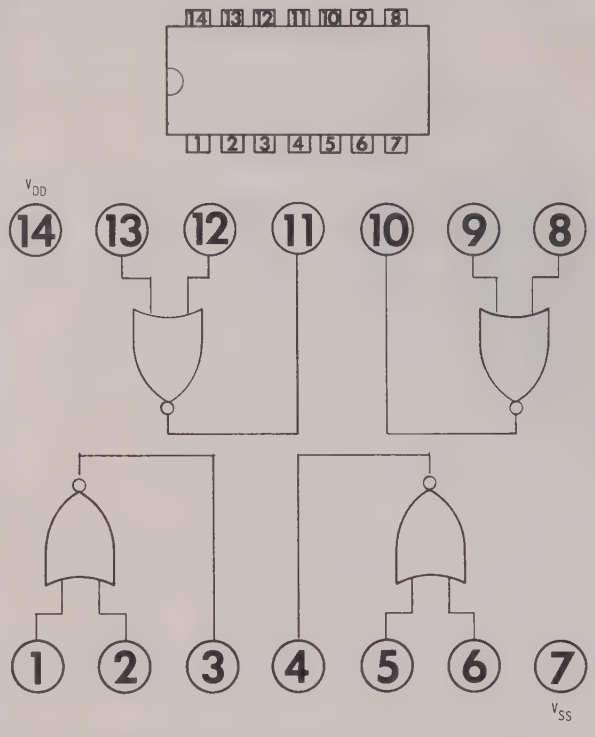
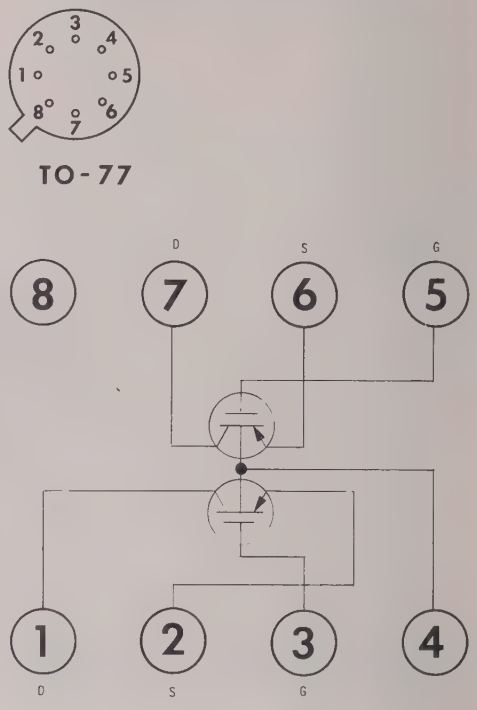


FIGURE 37. Case Outline - Integrated Circuits.

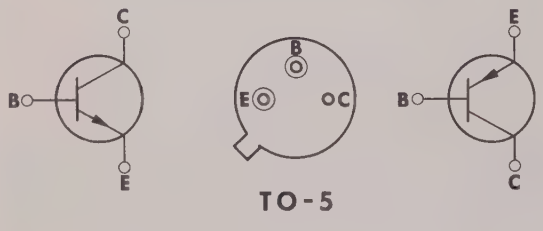
KEITHLEY PART NO. IC-108



KEITHLEY PART NO. TG-94



LEAD DESIG. TO-5



LEAD DESIG. TO-92

LEAD DESIG. TO-106

KEITHLEY PART NO. TG-77

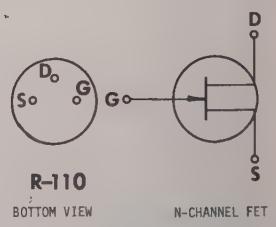
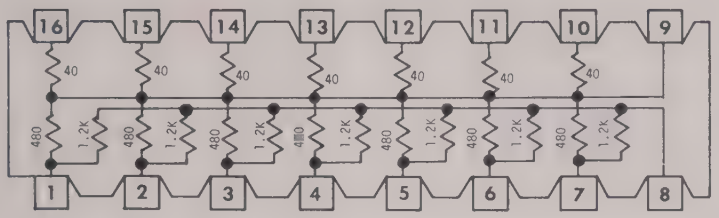
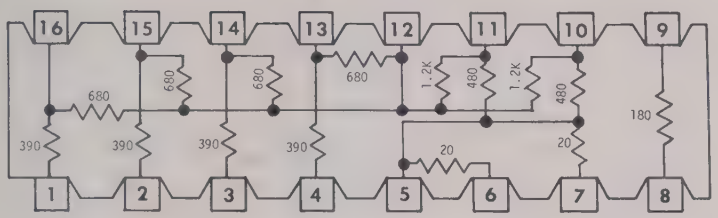


FIGURE 38. Case Outline - Transistors.

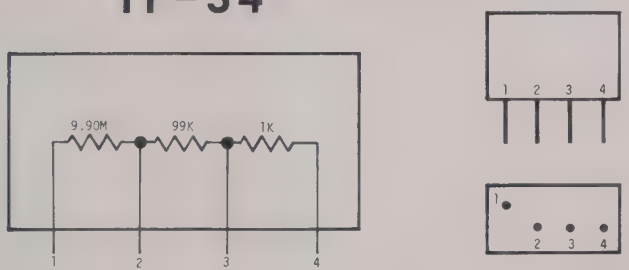
TF-30



TF-31



TF-34



TF-35

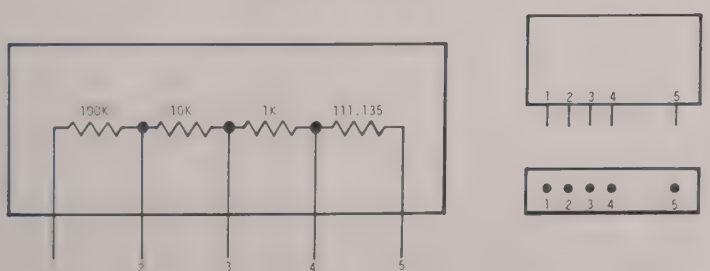
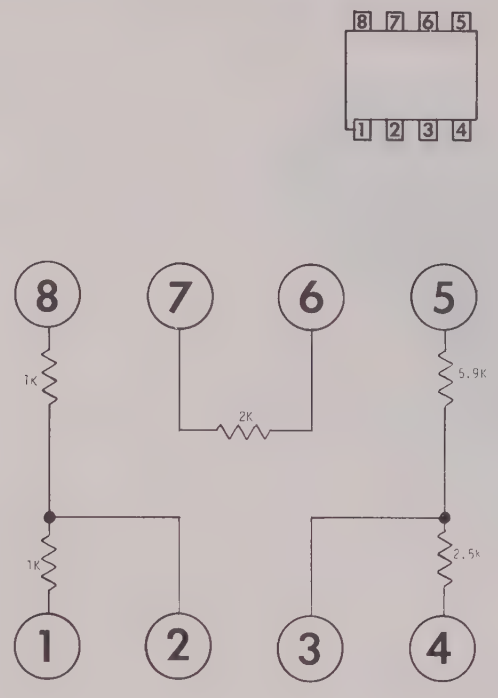
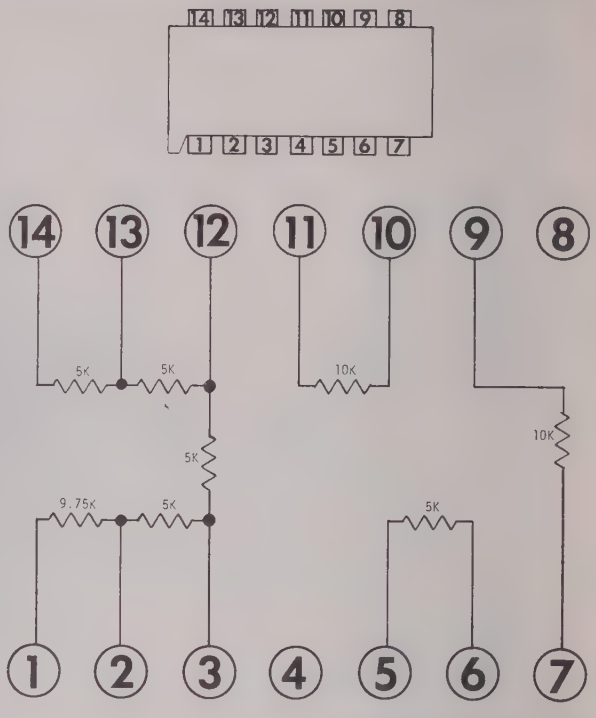


FIGURE 39. Case Outline - Thick Film Networks.

KEITHLEY PART NO. TF-36



KEITHLEY PART NO. TF-37



KEITHLEY PART NO. TF-39

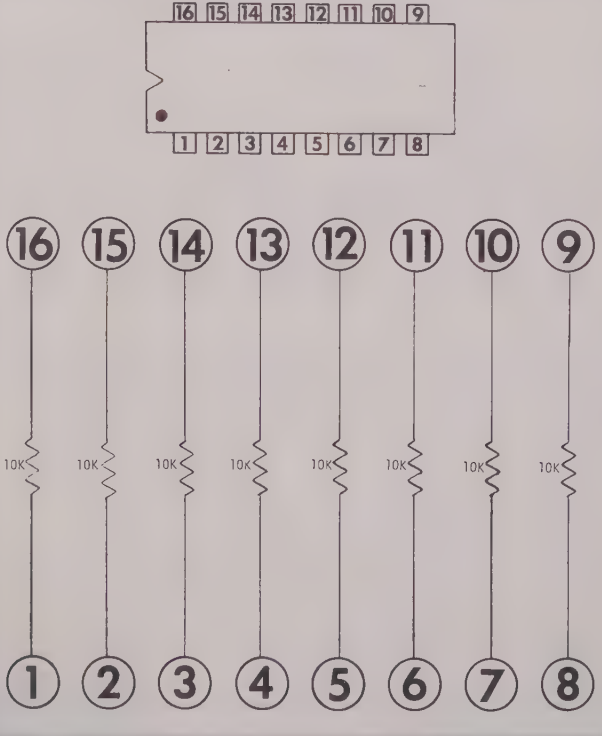


FIGURE 40. Case Outline - Thick Film Network.

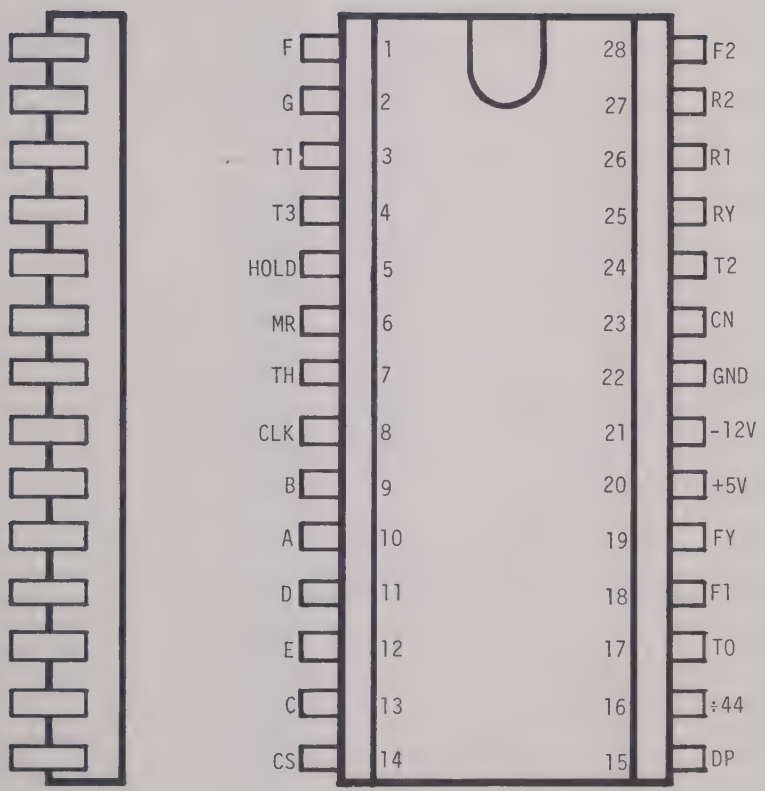


FIGURE 41. Case Outline - Custom LSI.

COMPONENTS LOCATED ON PC-349

Circuit Desig.	Location Code	Circuit Desig.	Location Code	Circuit Desig.	Location Code	Circuit Desig.	Location Code
C101	F-5	P102	J-4	R118	F-2	R205	C-8
C102	F-4	P103	J-3	R119	F-1	R206	B-7
C103	G-1	P104	H-2	R120	E-2	R208	H-7
C104	G-2	P105	H-5	R121	D-1	R209	J-7
C105	G-1	P106	J-5	R122	D-1	R210	J-7
C106	H-2	P107	G-2	R123	E-1	R211	J-6
C107	F-1	P108	G-4	R124	F-3	R212	B-6
C108	E-1	P109	G-4	R125	F-3	R213	C-6
C109	E-1	P110	F-3	R126	E-3	R214	C-8
C110	E-2	P111	F-3	R127	E-2	R215	B-8
C111	F-2	P114	B-4	R128	E-3	R216	C-6
C112	F-3			R129	E-3	R217	E-7
C113	E-3	P203	A-8	R130	D-2	R218	F-6
C114	E-4	P205	A-8	R131	D-2		
C115	C-3	P206	G-8	R132	C-6	S101	J-3
C116	C-4	P207	G-8	R133	E-6		
C117	C-4	P208	C-4	R134	D-4	S201	A-5
C118	C-4			R135	D-2	S202	A-6
C119	C-4	Q101	E-4	R136	E-4	S203	H-8
C120	E-5	Q102	E-2	R137	D-4		
		Q103	E-2	R138	E-6	T201	B-4
C201	B-6	Q104	D-2	R139	H-4		
C202	C-7	Q105	F-6	R140	H-5	TP101	F-6
C203	B-4	Q106	E-5	R141	J-5		
C204	B-2			R142	H-5	TP201	C-3
C206	B-1	Q201	B-6	R143	H-5	TP202	B-6
C207	C-3	Q202	G-6	R144	H-5		
		Q203	G-6	R145	J-4	U101	E-5
CR101	F-5	Q204	G-6	R146	J-4	U102	E-4
CR102	F-5	Q205	G-6	R147	G-4	U103	D-2
CR103	G-2	Q206	C-6	R148	G-4	U104	E-3
CR104	F-2	Q207	C-7	R149	F-4	U105	E-4
CR105	E-3			R150	G-5	U106	D-3
CR106	C-3	R101	F-4	R151	G-5	U107	D-3
CR108	J-6	R102	E-5	R152	G-5	U108	D-5
		R103	F-5	R153	G-5	U109	D-5
CR201	D-7	R104	D-5	R154	F-5	U110	C-5
CR202	C-7	R105	D-5	R155	C-5		
CR203	B-3	R106	E-5	R157	D-6	U201	D-7
CR204	C-2	R107	D-5	R158	C-5	U202	C-7
		R108	F-3	R159	J-2	U203	E-6
F101	J-5	R109	F-4	R160	F-2	U204	D-7
		R110	F-4	R161	D-3	U205	G-7
F201	A-7	R111	F-3	R162	D-3	U206	F-7
F202	A-7	R112	E-5	R163	H-6	U207	B-5
		R113	E-5			U208	C-2
J201	D-8	R114	J-1	R201	D-7		
J202	H-7	R115	F-3	R202	C-6		
		R116	H-2	R203	C-7		
P101	G-2	R117	G-2	R204	C-7	VR101	C-5
						VR102	C-3

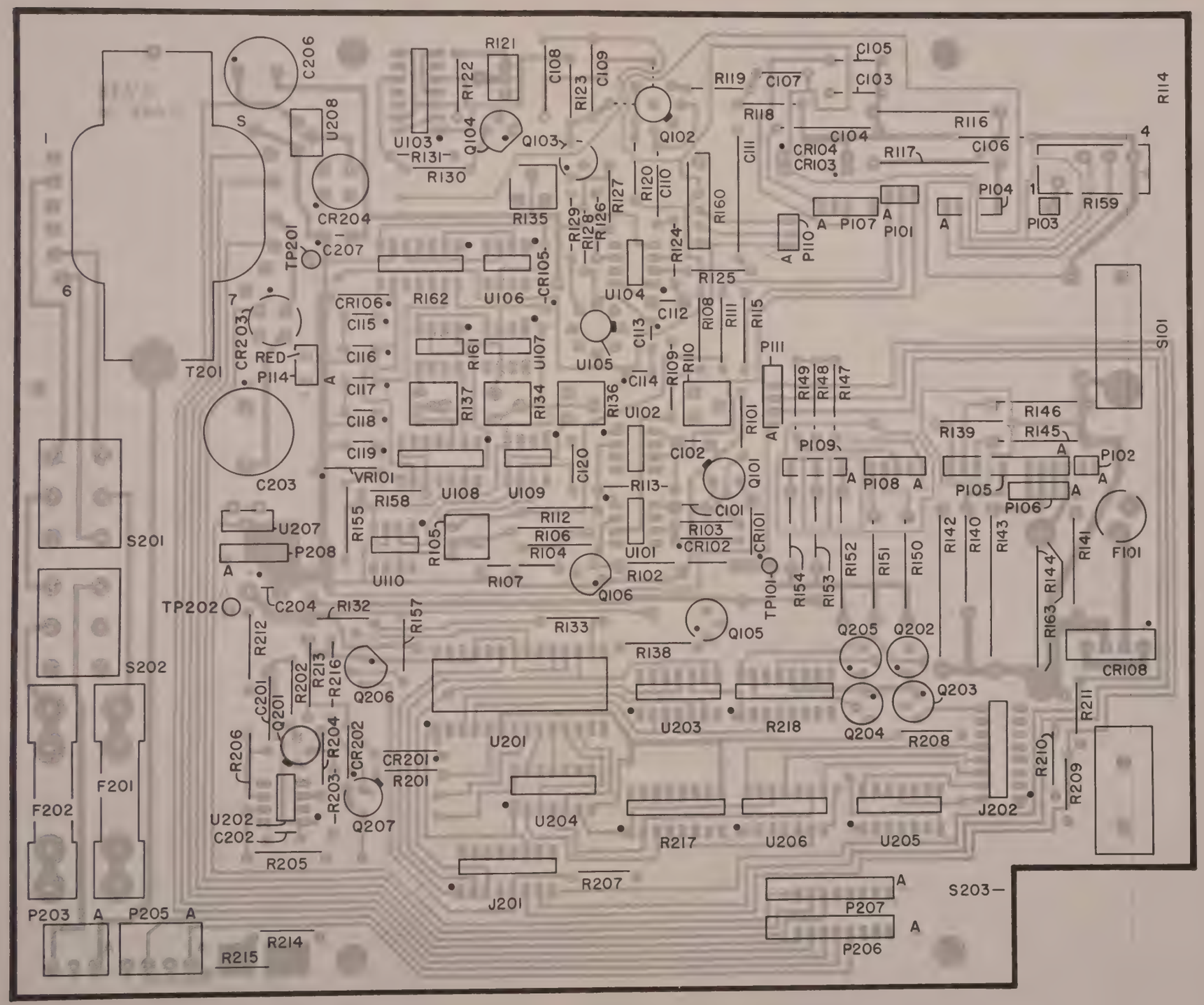


FIGURE 42. Component Layout, PC-349.

COMPONENTS LOCATED ON PC-352

Circuit Desig.	Location Code	Circuit Desig.	Location Code
C301	E-1	P301	A-2
C302	C-7		
C303	C-6	Q301	E-8
C304	C-4	Q302	E-8
C305	D-3	Q303	E-7
		Q304	E-7
CR301	F-2	Q305	E-7
CR302	F-2	Q306	E-7
CR303	F-2	Q307	E-6
CR304	F-2	Q308	E-6
CR305	F-2	Q309	E-6
CR306	F-1	Q310	E-6
CR307	F-2	Q311	E-6
CR308	F-1	Q312	E-5
CR309	F-1	Q313	E-5
CR310	D-1	Q314	E-5
		Q315	E-5
J302	G-2	Q316	E-5

Circuit Desig.	Location Code	Circuit Desig.	Location Code
Q317	E-4	U303	A-1
Q318	E-4	U304	B-1
Q319	E-4	U305	C-3
Q320	E-4	U306	E-1
		U307	B-4
R301	E-2	U308	C-4
R302	E-2	U309	D-3
R303	D-4	U310	C-7
R304	D-1	U311	C-6
R305	D-7	U312	C-5
R306	D-5	U313	D-6
R307	C-8	U314	D-7
R308	C-6	U315	D-6
R309	C-5	U316	D-5
R310	D-3	U317	D-4
		U318	D-2
U301	B-2	U319	C-1
U302	A-4	U320	D-1

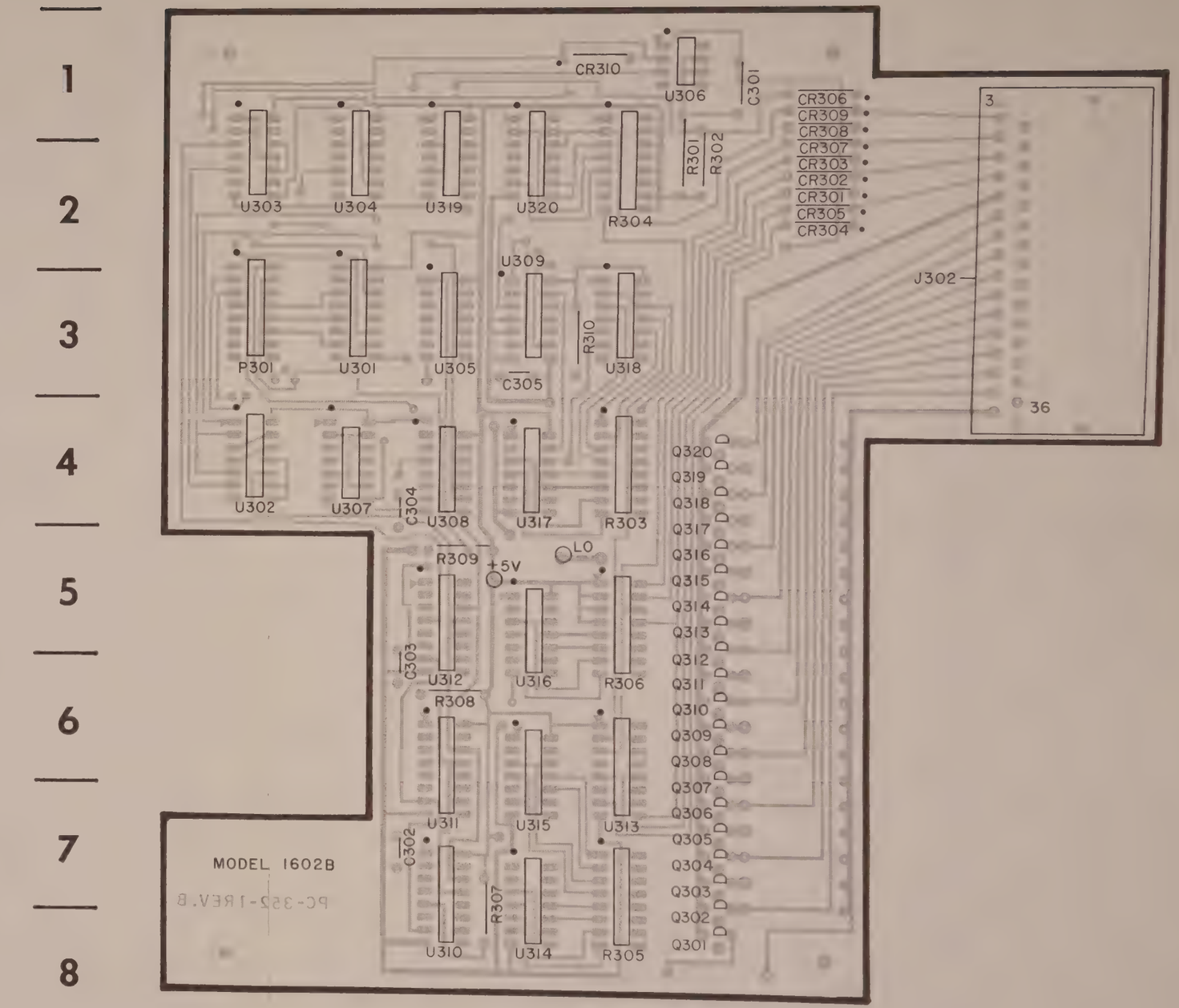


FIGURE 43. Component Layout, PC-352.

26590E

LTR	ECO NO	REVISION	DATE
E	4188	R106 WAS 5.9K	2-27-74
F	4167	R122 9.0K WAS 9.31K	2-6-74
G	4231	ADDED CONNECTIONS TO J101-A & J116	2-13-74

LTR	ECO NO	REVISION	DATE
A	4423	RELEASED	2-26-74
B	4462	ADDED VR102, R161, C120	3-7-74
C	4564	R106 IS 4.75K Ω (5K OR 5.9K Ω)	4-24-74
D	4573	R155 WAS 100MΩ	5-20-74

SEE DRWG. 26584E

SEE DRWG. 26584E

NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K-KILOHMS, M-MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. (pF-PICOFARADS)
3. ○ DENOTES FRONT PANEL CONTROL.
4. ● DENOTES REAR PANEL CONTROL.
5. ⊘ DENOTES INTERNAL ADJ.
6. → DENOTES CLOCKWISE ROTATION.
7. ⏚ DENOTES LINE CORD GREEN LEAD.
8. ⏚ DENOTES POWER SUPPLY LO.
9. (3) FLAGNOTES WITH SAME NUMBERS ARE CONNECTED.
10. ROTARY SWITCHES SHOWN IN C.C.W. POSITION.
11. OPTIONAL - MAY BE REMOVED AT INITIAL CAL.

HIGHEST REFERENCE DESIGNATIONS			
C120	CR108	F101	Q106
R163	S101	U110	J116
TP101	VR102	P114	

UNUSED REF. DESIGNATIONS		
R136	CR107	P112
P113	CR106	

1608
MODEL NEXT ASSEMBLY
USED ON

DO NOT SCALE THIS DRAWING

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX = ± .015 ANG = ±1°
XXX = ± .005 FRAC = ±1/64
SURFACE MAX 63

DATE 3-21-74 SCALE
DRN R.J.K
ENG APPR.
MATERIAL
FINISH

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

TITLE 1608 SCHEMATIC, INPUT AMP. & A/D CONVERTER
NO 26590E

NO 26584E

LTR	ECO NO.	REVISION	DATE
A	4425	RELEASED	7-24-74
B	4437	REASSIGNED J/P 204 AND P208	8-27-74
C	4452	SAFETY BNDS A, A AND B, CHASSIS	9-3-74
D	4566	CHANGED R206 FROM 75A TO 40.2	10-74
E	4813	REVISED R216 FROM 40.2 TO 40.2	75
F	4833	ENGINEERING CHANGE R213 FROM 4.64K TO 4.99K	6-75
G	4864	CHANGE RESISTANCE OF R212 FROM 3.32K TO 6.04K	6-5-75

NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K-KILOHMS, M-MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. (pF-PICOFARADS)
3. ○ DENOTES FRONT PANEL CONTROL.
4. ● DENOTES REAR PANEL CONTROL.
5. ⊘ DENOTES INTERNAL ADJ.
6. → DENOTES CLOCKWISE ROTATION.
7. ⏚ DENOTES LINE CORD GREEN LEAD.
8. ⏚ DENOTES POWER SUPPLY "LO".
9. (3) FLAGNOTES WITH SAME NUMBERS ARE CONNECTED.
10. ROTARY SWITCHES SHOWN IN C.C.W. POSITION.
11. WHEN THE H.P. DIGIT (H.P.#5082-7732) IS USED FOR DS201, PINS 4 AND 11 ARE INTERNALLY CONNECTED AND MUST BE CLIPPED OFF FOR THE DIGIT TO FUNCTION PROPERLY.

HIGHEST REFERENCE DESIGNATIONS			
C207	CR204	DS204	F204
Q207	R218	S203	U208
T201	J207	P208	TP202

UNUSED REF. DESIGNATIONS			
C205	J204		P201

1608				
MODEL	NEXT ASSEMBLY	QTY		

DO NOT SCALE THIS DRAWING

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX ± .015 ANG ± 1°; XXX ± .005 FRAC ± 1/64; SURFACE MAX 63

KEITHLEY INSTRUMENTS CLEVELAND OHIO

DATE 3-15-74 | SCALE ~ | DRN RJK | ENG APPR. | MATERIAL | FINISH

TITLE 160B SCHEMATIC DIGITAL LOGIC, DISPLAY & PWR SUPPLY

NO 26584E

26654E

LTR	ECO NO	REVISION	DATE
A	0415	RELEASED	9 24 74

J303 — CONNECTS TO P208 SEE DWG. 26584E

CONNECTS TO J201 SEE DWG. 26584E

+5V

P301 — A 13, B 12, D 10, E 9, F 11, G 4, T3 15, T2 3, T1 16, T0 2, POLARITY 5, "CN" (COUNT NOW), DP 1 6, DP 2 7, DP 3 8, DISPLAY HOLD 14 — P301

U301 A, B, C, D, E, F

U302 A, B, C, D

U303 A, B, C, D

U304 A, B, C, D

U305 A, B

U306 — TRIG, OUT — R301 100K, C301 0.1

CR310

U307 A, B, C, D

R304H 10K, R310 10K, C305 470pF

U308, U309

C304 470pF, R309 10K

C302 470pF, R307 10K

C303 470pF, R308 10K

U310, U311, U312 — CLK

U313 A, B, C, D, E, F

U314 A, B, C, D

U315 A, B, C, D

U316 A, B, C, D

U317 A, B, C, D

U318 A, B, C, D

U319 A, B

U320 A, B, C, D

R306D 10K, R305H 10K, R305G 10K, R305F 10K, R305E 10K, R306B 10K, R305D 10K, R305C 10K, R305B 10K, R305A 10K, R306A 10K, R306H 10K, R306G 10K, R306F 10K, R306E 10K, R304F 10K, R303E 10K, R303F 10K, R303H 10K, R304G 10K, R303G 10K, R303D 10K, R302 10K, R306C 10K, R303C 10K, R303B 10K, R303A 10K, R304A 10K, R304B 10K

Q301, Q302, Q303, Q304, Q305, Q306, Q307, Q308, Q309, Q310, Q311, Q312, Q313, Q314, Q315, Q316, Q317, Q318, Q319, Q320

CR301, CR302, CR303, CR304, CR305, CR306, CR307, CR308, CR309

J302 — 7 LO, 18 EXT. VOLTS, 25 ST 1, 36 1×10⁰, 17 2×10⁰, 35 4×10⁰, 16 8×10⁰, 5 ST 2, 34 1×10¹, 15 2×10¹, 33 4×10¹, 14 8×10¹, 24 ST 3, 32 1×10², 13 2×10², 31 4×10², 12 8×10², 26 ST 4, 30 1×10³, 11 OVERLOAD, 29 POLARITY, 6 ST 5, 10 FLAG, 28 FLAG, 22 FLAG RESET, 4 ST 6, 9 DP 1, 27 DP 2, 8 DP 3, 23 (HOLD) BCD, 3 DISPLAY (HOLD) — J302

NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K-KILOHMS, M-MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. (pF-PICOFARADS)
3. ⏚ DENOTES POWER SUPPLY "LO".

HIGHEST SCHEMATIC DESIGNATIONS USED

C305	CR310	J303
P301	Q320	R310
U320		

SCHEMATIC DESIGNATIONS NOT USED

J301		

1602.8			
MODEL	NEXT ASSEMBLY		QTY
USED ON			

DO NOT SCALE THIS DRAWING

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX ± .015, ANG ± 1°, XXX ± .005, FRAC ± 1/64, SURFACE MAX

DATE 9-9-74 DRN F.M. ENG APPR. (04/11) MATERIAL FINISH

SCALE —

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

TITLE SCHEMATIC DIGITAL OUTPUT

NO 26654E

KEITHLEY INSTRUMENTS, INC.

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